Year 12 Semester Two Examination, 2015

MARKING KEY

CHEMISTRY

Section One: Multiple-choice SOLUTIONS

Question	Correct response
1	A
2	B
3	D
4	B
5	D
6	B
7	A
8	C
9	A
10	B
11	D
12	A
13	B
14	C
15	D
16	B
17	C
18	C
19	D
20	C
21	B
22	D
23	C
24	B
25	B

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

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, do not erase or use correction fluid, and shade your new answer. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

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1. Which one of the following elements has the highest electronegativity?

(a) B
(b) Be
(c) Ba
(d) Bi

2. Which one of the following elements has the lowest atomic radius?

(a) N
(b) Ne
(c) Na
(d) Ni

3. Which one of the following pairs of solutions will **not** form a white precipitate when mixed together?

(a) sodium carbonate and magnesium chloride
(b) ammonium carbonate and zinc chloride
(c) copper(II) sulfate, and barium nitrate
(d) sodium iodide and silver nitrate

4. Which one of the statements below best describes the relationship between the solubility of gases in water and the temperature of the water?

(a) As the temperature of the water increases the solubility of gases increases.
(b) As the temperature of the water increases the solubility of gases decreases.
(c) The temperature of the water has no effect on the solubility of gases.
(d) The relationship between the solubility of gases in water and temperature is different for every gas so we can't make a generalised statement.

5. Examine the first five ionisation energies of element **A** below.

	1st	2nd	3rd	4th	5th
Ionisation Energies (kJ mol^{-1})	793	905	3 392	4 167	5 111

Which one of the following is the most likely formula of the oxide of element **A**?

(a) A_2O_3
(b) AO
(c) A_2O
(d) AO

6. Which of the following will conduct an electric current?

i molten sulfur
ii a saturated solution of silver sulfate
iii solid silver
iv solid silver sulfide

(a) i and ii only
(b) **ii and iii only**
(c) i and iv only
(d) i, ii and iv only

7. In which one of the following substances are dispersion forces the most significant type of intermolecular force?

(a) solid carbon dioxide
(b) liquid ethanol
(c) solid butanoic acid
(d) solid sodium chloride

8. Which one of the following species contains lone (non-bonding) pairs of valence electrons?

(a) C_2H_4
(b) NH_4^+
(c) H_2S
(d) CH_4

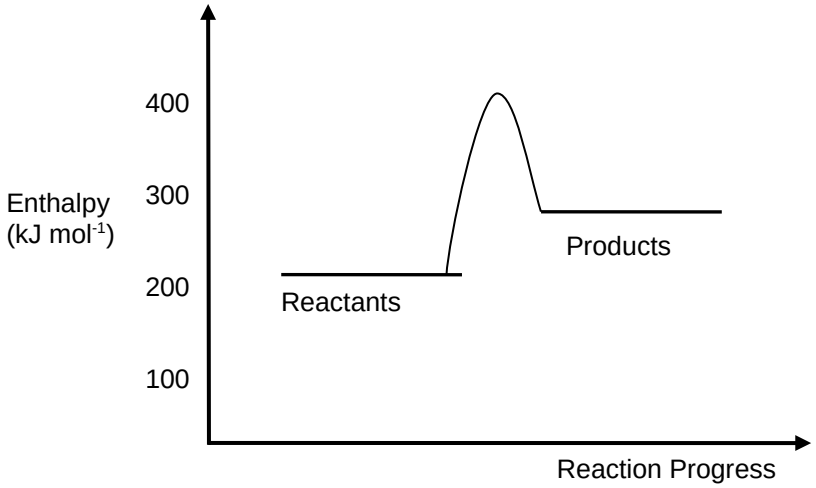
9. Which one of the following substances is likely to be the most soluble in water?

(a) HF
(b) H_2S
(c) H_2
(d) CH_4

10. Which one of the following statements about absolute zero is **false**?

(a) Absolute zero is -273.15 °C
(b) Gases could exist at absolute zero.
(c) It is impossible to reach temperatures below absolute zero.
(d) At absolute zero the kinetic energy of particles would be zero.

11. An energy profile diagram for a chemical reaction is shown below.



Estimate the activation energy for the **reverse** reaction.

(a) + 400 kJ mol^{-1}
(b) + 200 kJ mol^{-1}
(c) - 200 kJ mol^{-1}
(d) + 120 kJ mol^{-1}

12. Which one of the following correctly arranges 0.01 mol L^{-1} solutions of the substances in the order of decreasing pH, from highest to lowest?

(a)	**$Ca(OH)_2$**	**NaOH**	**Na_2CO_3**	**$NaNO_3$**	**NH_4NO_3**
(b)	NaOH	$Ca(OH)_2$	Na_2CO_3	NH_4NO_3	$NaNO_3$
(c)	$Ca(OH)_2$	NaOH	$NaNO_3$	Na_2CO_3	NH_4NO_3
(d)	NaOH	$Ca(OH)_2$	Na_2CO_3	$NaNO_3$	NH_4NO_3

13. Consider the equilibrium system below:

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

Which one of the following statements is **false**?

(a) NH_3 is the conjugate base of NH_4^+.
(b) The water is acting as a base.
(c) Addition of water will favour the forward reaction.
(d) The system can oppose an increase in pH by favouring the reverse reaction.

14. Which one of the following 1.0 mol L^{-1} solutions will have the lowest pH?

(a) $HC\ell(aq)$
(b) $H_3PO_4(aq)$
(c) $H_2SO_4(aq)$
(d) $NH_4C\ell(aq)$

15. Which one of the following species listed below contains sulfur with the highest oxidation state?

(a) H_2SO_3
(b) S_8
(c) SO_2
(d) $MgSO_4$

16. In which one of the following reactions is oxygen undergoing disproportionation (being oxidised and reduced)?

(a) $2\ C\ell O^- + 4\ H^+ \rightarrow C\ell_2 + 2\ Cl^- + 2\ H_2O$
(b) $2\ H_2O_2 \rightarrow O_2 + 2\ H_2O$
(c) $5\ MnO_2 + 4\ H^+ \rightarrow 2\ MnO_4^- + 3\ Mn^{2+} + 2\ H_2O$
(d) $2\ FeO + 3\ CO_2 \rightarrow Fe_2O_3 + 3\ CO$

17. By referring to the table of standard electrode potentials on the Chemistry Data Sheet, predict which one of the following pairs of substances will undergo a chemical reaction
(a) Iron(III) nitrate solution and sodium chloride
(b) Sodium chloride solution and solid iodine
(c) Gaseous chlorine and solid silver
(d) Hydrogen peroxide solution and lead(II) sulfate solution

18. Corrosion occurs when a metal is oxidised to its ions. An initial stage in the corrosion of iron can be represented as:

$Fe(s) \rightarrow Fe^{2+}(aq) + 2\,e^-$

The Iron hulls of ships can be protected from corrosion by adding separate pieces of magnesium to outside of the hull. Which one of the following best explains how this protects iron from corrosion?

(a) The iron reacts with the magnesium instead of the water.
(b) Magnesium protects the iron because it is less reactive than the iron
(c) Magnesium is oxidised in preference to the iron.
(d) The magnesium prevents iron being exposed to oxygen.

19. Which one of the following has a different empirical formula to the other three?

(a) butanoic acid
(b) methyl propanoate
(c) ethanal
(d) propyl propanoate

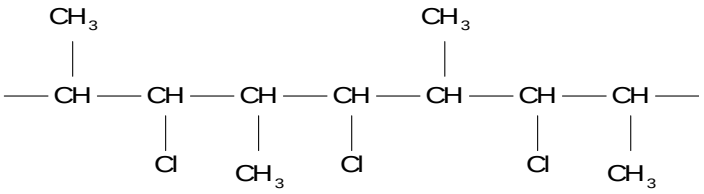
20. Which one of the following pairs of compounds would form propyl methanoate when warmed with concentrated sulfuric acid?

(a) CH_3OH and CH_3CH_2COOH
(b) $CH_3CH_2CH_2OH$ and CH_3OH
(c) HCOOH and $CH_3CH_2CH_2OH$
(d) $CH_3CH_2CH_3$ and HCOOH

21. Which one of the following is an addition reaction?

(a) $CH_3CH_2CH_2CH_2CH_3 + Br_2 \rightarrow CH_3CHBrCH_2CH_2CH_3 + HBr$
(b) $CH_3CHCHCH_2CH_3 + H_2 \rightarrow CH_3(CH_2)_3CH_3$
(c) $C_6H_6 + CH_3C\ell \rightarrow C_6H_5CH_3 + HC\ell$
(d) n $HOCH_2CH_2OH$ + n HOOCCOOH → n (-$OCH_2CH_2OCOCOO$-) + 2n H_2O

22. Examine the section of the polymer shown below.



Which one of the following is the correct name for the monomer used to make this polymer?

(a) 1-methyl-2-chloroethene
(b) 1-chloroprop-2-ene
(c) 2-chloropropene
(d) 1-chloropropene

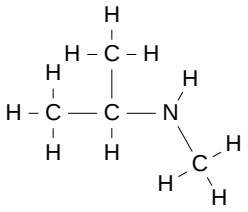
23. Which one of the following is the correct half-equation for the oxidation of propan-1-ol to propanoic acid?

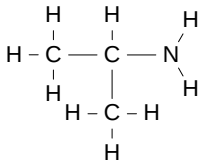
(a) $CH_3CH_2CH_2OH(aq) + H_2O(\ell) \rightarrow CH_3CH_2COOH(aq) + 2\ H^+(aq) + 2\ e^-$
(b) $CH_3CH_2CH_2OH(aq) \rightarrow CH_3CH_2CHO(aq) + 2\ H^+(aq) + 2\ e^-$
(c) $CH_3CH_2CH_2OH(aq) + H_2O(\ell) \rightarrow CH_3CH_2COOH(aq) + 4\ H^+(aq) + 4\ e^-$
(d) $CH_3CH_2CH_2OH(aq) + O_2(g) \rightarrow CH_3CH_2COOH(aq) + H_2O(\ell)$

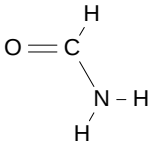
24. Which one of the following is an α(alpha)-amino acid?

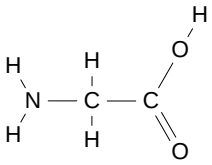
(a) $CH_3CNH_2COOCH_3$
(b) CH_3CNH_2COOH
(c) $NH_2CH_2CH_2COOH$
(d) CH_3CONH_2

25. Which one of the following is a primary amine?

(a) 

(b) 

(c) 

(d) 

End of Section One

Section Two: Short answer **35% (70 Marks)**

This section has **11** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

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: 60 minutes.

Question 26 **(4 marks)**

Write balanced ionic equations for any reactions that occur in the following situations. If no reaction occurs, state **No Reaction**.

(a) Solid copper(II) carbonate is added to dilute hydrochloric acid. (2 marks)

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

Description	Marks
correct species	1
equation balanced	1
Total	**2**

(b) Barium nitrate solution is added to sodium hydroxide solution. (2 marks)

No Reaction (both products soluble)

Description	Marks
No Reaction	2
Total	**2**

Question 27 **(4 marks)**

For each of the following reactions, describe expected observations, including any:

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

(a) Solid sodium hydrogencarbonate is added to dilute hydrochloric acid. (2 marks)

$NaHCO_3(s) + H^+(aq) \rightarrow Na^+(aq) + H_2O(\ell) + CO_2(g)$

Description	Marks
white solid dissolves to give colourless solution	1
colourless, odourless gas produced	1
Total	**2**

(b) Iron filings are added to silver nitrate solution. (2 marks)

$Fe(s) + 2\ Ag^+(aq) \rightarrow 2\ Ag(s) + Fe^{2+}(aq)$

Description	Marks
(colourless) solution becomes pale green	1
silvery/grey solid produced	1
Total	**2**

Question 28 **(4 marks)**

The table below shows the first four ionisation energies of aluminium.

	1st	2nd	3rd	4th
Ionisation Energies ($kJ\ mol^{-1}$)	577	1817	2744	11577

(a) Explain why the difference between the 3rd and 4th ionisation energies is greater than the difference between 2nd and 3rd ionisation energies.

Description	Marks
The 4th electron is being removed from a different shell / higher energy level than the 3rd electron	1
significantly more energy required	1
due to reduced shielding / increased distance from nucleus	1
2nd and 3rd electron removed from same shell / energy level so similar shielding / distance from nucleus	1
Total	**4**

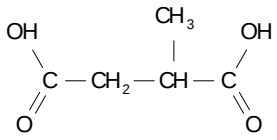
Question 29 **(6 marks)**

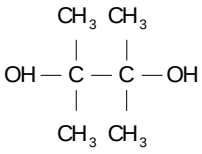
75.0 mL of sulfuric acid, with a mass of 94.5 g and a concentration of 37.0% by mass was spilt from a car battery. To treat the spill, 350 mL of 2.00 mol L^{-1} sodium hydroxide solution was added to the spilt acid and 10.0 litres of water added to dilute the resulting solution. Calculate the pH of the final solution.

Description	Marks
$m(H_2SO_4) = 94.5 \times 37/100 = 34.965$ g	1
$n(H_2SO_4) = m / M = 34.965 / 98.076 = 0.3565$ mol	1
$n(NaOH) = c \times V = 2.00 \times 0.350 = 0.700$	1
$H_2SO_4 + 2\ NaOH \rightarrow Na_2SO_4 + 2\ H_2O$ (or recognition that mole ratio is 1:2) $n(H^+)_{excess} = (0.3565 \times 2) - 0.700 = 0.0130$ mol	1
$c(H^+)_{final} = n / V = 0.0130 / (10.0 + 0.350 + 0.075) = 0.001247$ mol L^{-1}	1
$pH = -\log(H^+) = -\log(0.001247)$ **= 2.90**	1
Total	**6**

Question 30 **(4 marks)**

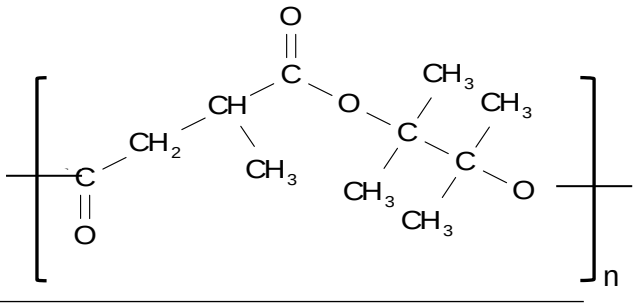
Look at the two molecules below.





(a) Draw a section of the polymer that would be produced from these two molecules.

(2 marks)



Description	Marks
correct structure of repeating unit	1
use of 'n' to represent repeat / at least two repeating units shown in diagram	1
Total	**2**

(b) Write a balanced molecular equation for the formation of this polymer. (2 marks)

$n\ HO_2CCH_2CHCH_3CO_2H + n\ HOC(CH_3)_2C(CH_3)_2OH \rightarrow (-CCH_2CHCH_3CO_2C(CH_3)_2C(CH_3)_2O-)_n + 2n\ H_2O$

Description	Marks
correct species (including polymer)	1
inclusion of 2n H_2O (to balance the equation)	1
Total	**2**

Question 31 **(8 marks)**

A chemist was required to conduct analysis to check that the exact mass of magnesium carbonate present in a 0.500 g indigestion tablet was 460 mg, as claimed by the manufacturer. He decided to carry out the experiment using an indirect (back) titration. This type of titration involves adding excess acid to the tablet, carrying out a titration to calculate the amount of unreacted (excess) acid and using this value to calculate the amount of acid that reacts with the carbonate in the original tablet.

(a) Explain why an indirect (back) titration is the method used. (2 marks)

Description	Marks
magnesium carbonate is insoluble	1
therefore impossible to titrate directly / cannot make up solution from the tablet (or similar explanation)	1
Total	**2**

(b) The chemist had a solution of 1.00 mol L^{-1} hydrochloric acid and a standardised solution of 0.250 mol L^{-1} sodium carbonate to use in the titration. He was aiming to have a titre of the sodium carbonate of approximately 20 mL. Calculate the approximate volume of the hydrochloric acid he should add to each tablet.
(6 marks)

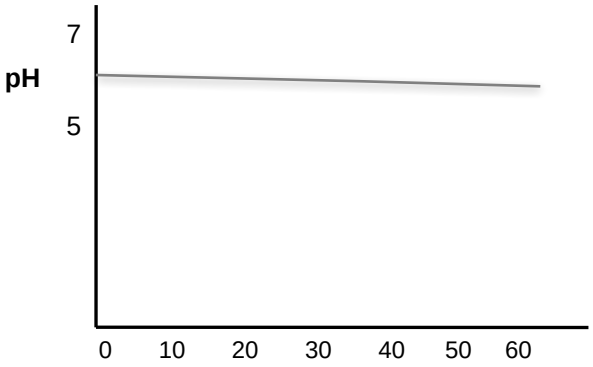
Description	Marks
$n(Na_2CO_3)_{target} = c \times V = 0.250 \times 0.020 = 0.0050$ mol	1
$Na_2CO_3 + 2\ HC\ell \rightarrow 2\ NaC\ell + H_2O + CO_2$ $n(HC\ell)_{excess\ target} = m / M = (2/1) \times 0.0050$ mol $= 0.010$ mol	1
$n(MgCO_3)_{in\ tablet} = m / M = 0.460 / 84.32 = 0.005455$ mol	1
$MgCO_3 + 2\ HC\ell \rightarrow 2\ MgC\ell_2 + H_2O + CO_2$ $n(HC\ell)_{that\ will\ react\ with\ each\ tablet} = (2/1) \times 0.005455$ mol $= 0.0109$ mol	1
$n(HC\ell)_{that\ will\ produce\ required\ excess} = 0.0109 + 0.010$ mol $= 0.0209$ mol	1
$V(HC\ell)_{required} = n / c = 0.0209 / 1.00 = 20.9$ mL or 21 mL *accept 20 mL as final answer if correct working shown*	1
Total	**6**

Question 32 **(6 marks)**

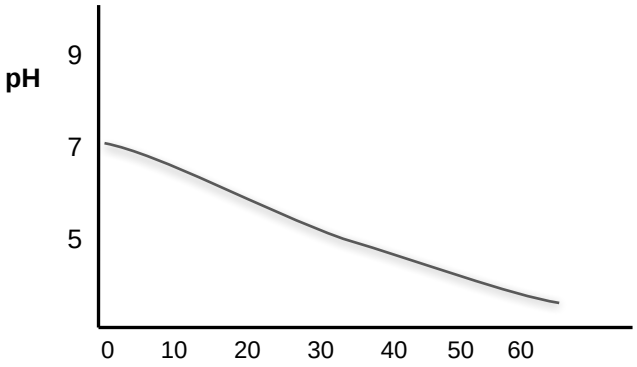
The following two graphs show the effect on the pH of adding dilute hydrochloric acid drop by drop to:

Solution 1: Ammonia (NH_3) solution mixed with ammonium chloride ($NH_4C\ell$) solution
Solution 2: Sodium chloride ($NaC\ell$) solution.

Graph 1. The change in pH when adding dilute $HC\ell$ to an aqueous mixture of $NH_3/NH_4C\ell$



Graph 2. The change in pH when adding dilute $HC\ell$ to a solution of NaCl

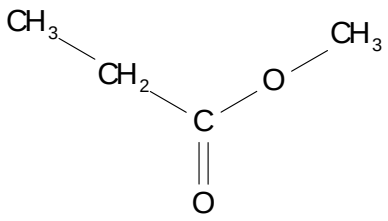
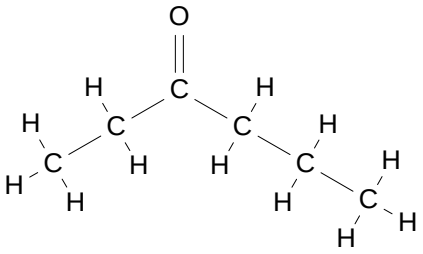
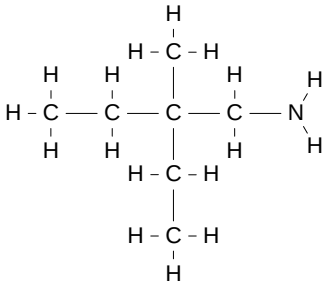


Explain, using equations, the differences between the shape of the two graphs.

Description	Marks
Solution 1 is a buffer solution	1
Equation to show $NH_3/NH_4C\ell$ system: $NH_3(aq) + H^+(aq) \rightleftharpoons NH_4^+(aq)$ *or:* $NH_3(aq) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$	1
as acid is added the system moves to the right / forward reaction is favoured	1
therefore change in pH is minimised / solution opposes increase in concentration of hydrogen ions (from the acid) / or similar correct explanation	1
Solution 2 is un-buffered / not a buffer solution	1
addition of $HC\ell$ reduces the pH of because it increases the concentration of $H^+(aq)$	1
Total	**6**

Question 33 **(3 marks)**

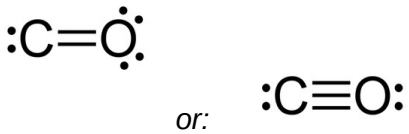
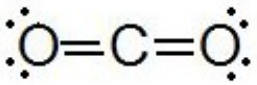
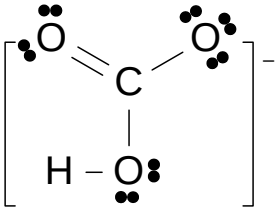
Complete the following table showing the structure and names of four organic compounds.

Structure	IUPAC Name
	methyl propanoate
	3-hexanone
	**1-amino-2-ethyl-2-methylbutane**

Description	Marks
One mark for each correct structure / name	1-3
Total	**3**

Question 34 **(11 marks)**

(a) For each species listed in the table below, draw the structural formula, representing **all** valence shell electron pairs as **:** or as **—** and indicate the shape of the species by a sketch or a name. (6 marks)

Species	Electron Dot Diagram (Lewis diagram)	Shape
Carbon monoxide, CO	 *or:*	**linear**
Carbon dioxide, CO_2		**linear**
hydrogencarbonate, HCO_3^-		**trigonal planar**

Description	Marks
One mark for each correct structure / name	1-6
Total	**6**

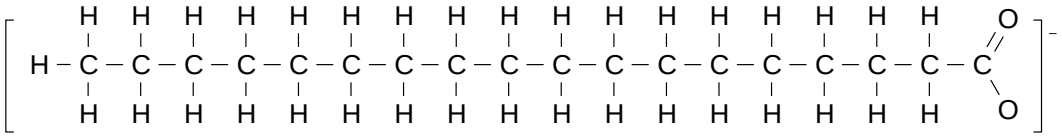
(b) Compare the polarities of the carbon dioxide and carbon monoxide molecules, explaining the cause of any differences. (2 marks)

Description	Marks
carbon monoxide is a polar molecule due to just one polar bond / overall net dipole	1
carbon dioxide non-polar due to symmetrical arrangement of polar bonds / no overall net dipole	1
Total	**2**

(c) Sodium hydrogencarbonate is soluble in water. Describe, with the aid of a labelled diagram, the processes occurring when solid sodium hydrogencarbonate dissolves in water. (3 marks)

Description	Marks
Labelled diagram showing:	
existing hydrogen bonding in water	1
ionic lattice for sodium hydrogencarbonate	1
ion-dipole bonding between water molecules and hydrogencarbonate ions	1
Total	**3**

(d) Below is the structure of the stearate ion, $CH_3(CH_2)_{16}COO^-$, which is present in a number of types of soap.



Explain why the stearate ion is soluble in water **and** non-poplar substances such as oil and grease. (3 marks)

Description	Marks
ion-dipole bonding can occur between the charged 'head' / end of the stearate molecule and water	1
dispersion forces can occur between the non-polar hydrocarbon chain / part of the molecule	1
and the non-polar molecules in oil or grease	1
Total	**3**

Question 35 **(10 marks)**

Consider the reversible reaction below which is used in the production of quick lime (calcium oxide).

$CaCO_3(s)$ + heat $\rightleftharpoons$ $CaO(s)$ + $CO_2(g)$

(a) Write the equilibrium constant expression for this reaction. (1 mark)

Description	Marks
$K = [CO_2]$	1
Total	**1**

(b) For each of the following changes made to the system at equilibrium, predict the changes to the yield of the reaction once equilibrium is re-established, using the terms increase, decrease or no change. Provide a reason for your prediction in each case. (9 marks)

Imposed Change	Effect on Yield	Explanation
Increase temperature	**increases**	**Forward endothermic reaction favoured to oppose the increase in temperature**

Description	Marks
increases yield	1
forward reaction is endothermic	1
mention of opposing/counteracting the increase in temperature	1
Total	**3**

Increase pressure	**reduces**	**Equilibrium shifts to the left / reverse reaction favoured to oppose the increase of pressure because there are less gaseous moles/molecules on the left hand side / as reactants**

Description	Marks
reduces yield	1
mention of opposing/counteracting the increase in pressure	1
less gaseous moles/molecules on the left hand side / as reactants	1
Total	**3**

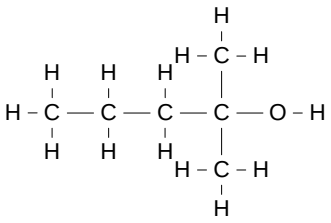
Remove calcium oxide as it is produced	**No change**	**Calcium oxide is a solid so no effect on position of equilibrium / concentration of components in system**

Description	Marks
no change on yield	1
mention of calcium oxide is a solid	1
solid doesn't affect concentration / not present in equilibrium constant expression	1
Total	**3**

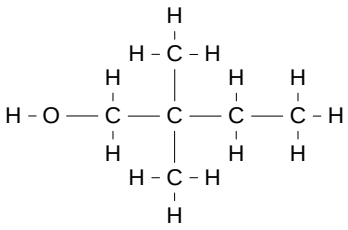
Question 36 **(7 marks)**

Consider the two molecules below.

Molecule A



Molecule B



(a) Write the IUPAC name of the two molecules. (2 marks)

Molecule A

Description	Marks
2-methylpentan-2-ol *accept:* 2-methyl-2-pentanol	1
Total	**1**

Molecule B

Description	Marks
2,2-dimethylbutan-1-ol *accept:* 2,2-dimethyl-1-butanol	1
Total	**1**

(b) Describe a chemical test that could be used to distinguish between them. State the expected observations for both substances. (5 marks)

Substance	Description of chemical test	Expected observations
Molecule A	*either:* **add a few drops / small amount of acidified (potassium) permanganate solution to both substances** *or:* **add a few drops / small amount acidified (potassium/sodium) dichromate solution to both substances**	**No colour change**
Molecule B		*either:* **purple colour changes to colourless** *or:* **orange colour changes to green**

Description	Marks
Correct description of test. Must include acidification and that the permanganate or dichromate are used in solution form for both marks	1-2
Molecule A – No reaction	1
Molecule B – initial colour	1
Molecule B – final colour	1
Total	**5**

End of Section Two

Section Three: Extended answer 40% (80 Marks)

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

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

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: 70 minutes.

Question 37 (19 marks)

This question is about the production of sulfuric acid (H_2SO_4). This process is carried out through a number of steps:

Step 1
Liquid sulfur is reacted with dry air to produce sulfur dioxide (SO_2).

Step 2
The sulfur dioxide is oxidised to sulfur trioxide using vanadium(V) oxide as a catalyst. This step is called the Contact Process. The equation for the reaction is shown below.

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g) \qquad \Delta H = -196\ kJ\ mol^{-1}$$

Step 3
Concentrated sulfuric acid (98.0 % by mass) is used to dissolve sulfur trioxide where it forms oleum ($H_2S_2O_7$).

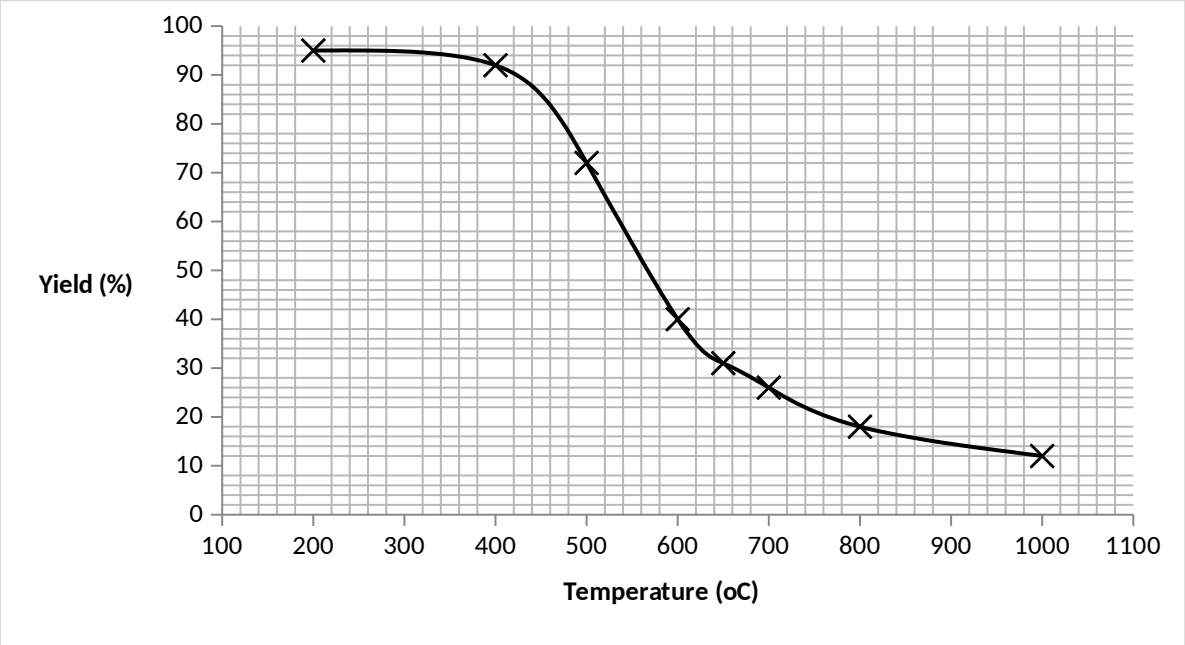
Step 4
The oleum is mixed with water to obtain more sulfuric acid.

A team of chemical engineers carried out step 2 at a variety of temperatures to inform decisions about the optimum conditions for the reaction. Their results are shown on the next page.

Table 1. Yield of sulphur trioxide for contact process reaction carried out at 150 kPa pressure, with a V_2O_5 catalyst at a range of temperatures.

Temperature of reaction vessel (°C)	Yield of SO_3 (%)
200	95
400	92
500	72
600	40
650	31
700	26
800	18
1000	12

(a) On the grid below, display this data with a line graph. (4 marks)



Description	Marks
correct scales (temperature on horizontal axis)	1
scales labelled, including units	1
correct plot	1
line drawn	1
Total	**4**

(b) Use your graph to predict the yield of the reaction at 550 °C. (1 mark)

Description	Marks
54 – 58%	1
Total	**1**

(c) Describe the trend shown by these results. (2 marks)

Description	Marks
the yield decreases with increasing temperature	1
Some description related to the shape, e.g. the yield changes significantly between 30 – 90 degrees / little change to yield at when changing temperature at low or high temperatures	1
Total	**3**

(d) As a result of these findings, the chemical engineer decided to operate the sulfuric acid plant at a temperature of 200 °C. However, the amount of sulphur dioxide produced was very low. Suggest a reason for this. (1 mark)

Description	Marks
the reaction would be too slow (at this temperature)	1
Total	**1**

(e) After further tests, it was decided to operate the plant at 400 °C. With reference to your graph, explain why this temperature, and not a higher temperature, was chosen. (2 marks)

Description	Marks
There is a relatively high yield (92%) at this temperature	1
The yield drops significantly at temperatures higher than 400 °C	1
Total	**2**

(f) Assuming a yield of 92.0%, Calculate the volume of oxygen, at 400 °C and a pressure of 150 kPa, required to produce 1.00 tonne (1.00×10^6 g) of sulphur trioxide in the Contact Process: (4 marks)

$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$

Description	Marks
$n(SO_3) = m / M = 1.00 \times 10^6 / 80.07 = 1.2489 \times 10^4$ mol	1
$n(O_2)_{required} = (1/2) \times n(SO_3) \times (100/92)$ $= (1/2) \times 1.2489 \times 10^4 \times (100/92) = 6.787 \times 10^3$ mol	1
PV = nRT V = nRT / P = $(6.787 \times 10^3 \times 8.314 \times 673.15) / 150$ **= 2.53×10^5 L**	1
units and correct significant figures (3)	1
Total	**4**

(g) Sulfuric acid is used to produce agricultural fertiliser, including superphosphate, which is a mixture of two calcium salts. The reaction is shown below:

$$Ca_3(PO_4)_2(s) + 2\ H_2SO_4(aq) + 4\ H_2O(\ell) \rightarrow Ca(H_2PO_4)_2(s) + 2\ CaSO_4{\cdot}2H_2O(s)$$

If 98.0 % (by mass) sulfuric acid is used, calculate the mass of the super phosphate that can be produced from 1.00 tonne of the sulfuric acid. (assume 100% yield)

(5 marks)

Description	Marks
$m(H_2SO_4) = (98/100) \times 1.00 \times 10^6 = 9.80 \times 10^5$ g	1
$n(H_2SO_4) = m / M = 9.80 \times 10^5 / 98.086 = 9.991 \times 10^3$ mol	1
$n(Ca(H_2PO_4)_2) = (1/2) \times n(H_2SO_4) = 4.996 \times 10^3$ mol $m(Ca(H_2PO_4)_2) = n \times M = 4.996 \times 10^3 \times 234.052 = 1.169 \times 10^6$ g	1
$n(CaSO_4{\cdot}2H_2O) = (2/2) \times n(H_2SO_4) = 9.991 \times 10^3$ mol $m(CaSO_4{\cdot}2H_2O) = n \times M = 9.991 \times 10^3 \times 172.182 = 1.720 \times 10^6$ g	1
total mass = $1.169 \times 10^6 + 1.720 \times 10^6$ **$= 2.89 \times 10^6$ g** *or:* **= 2.89 tonnes**	1
Total	**5**

Question 38 **(12 marks)**

Dopamine is a primary amine that acts as a neurotransmitter, a chemical that send signals between nerve cells. Levels of dopamine in the brain have been linked to a number of medical conditions, including Parkinson's disease and ADHD. Some additive drugs increase the production of dopamine. Dopamine contains carbon, nitrogen, hydrogen and oxygen. In this question you will work out the formula of dopamine.

Two samples of were analysed to determine its empirical formula.

A 12.1 g sample was combusted in oxygen and produced 27.6 g of carbon dioxide and 7.87 g of water.

A separate 17.2 g sample was found to contain 1.57 g of nitrogen.

(a) Determine the empirical formula of dopamine (7 marks)

Description					**Marks**
Sample 1					
$m(CO_2) = 27.6 \times (12.01/44.01) = 7.53$ g $\%(CO_2) = (7.53 / 12.1) \times 100 = 62.2$ %					1
$m(H) = 7.87 \times (2.016/18.016) = 0.881$ g $\%(H) = (0.881 / 12.1) \times 100 = 7.28$ %					1
Sample 2					
$\%(N) = (1.57/ 17.2) \times 100 = 9.13$ %					1
Oxygen					
$\%(O) = 100 - 62.2 - 7.28 - 9.13 = 21.4\%$					1
	C	**H**	**N**	**O**	
mass (%)	62.2	7.28	9.13	21.4	
mole ratio	62.2/12.01	7.28/1.008	9.13/14.01	21.4/16.00	
	5.187	7.222	0.6517	1.33	1
divide by smallest	5.187/0.6517	7.222/0.6517	0.6517/0.6517	1.33/0.6517	
	7.96	11.07	1.0	2.05	1
round up	8	11	1	2	
Empirical Formula	**$C_8H_{11}NO_2$**				1
				Total	**7**

(b) Dopamine is a weak monoprotic base (it can only accept one proton). 10.0 g of dopamine was dissolved in distilled water and the solution made up to 250.0 mL. When titrated against 0.250 mol L^{-1} hydrochloric acid, 25.00 mL of this solution required 26.1 mL of the acid for neutralisation.

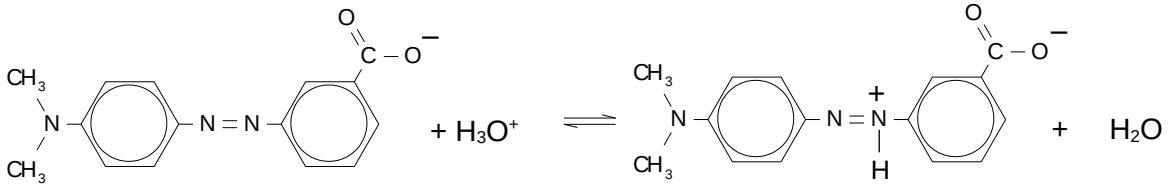
From this data, calculate the molecular mass of dopamine, and hence determine the molecular formula of dopamine. (5 marks)

Description	Marks
$n(HC\ell) = c \times V = 0.250 \times 0.0261 = 6.525 \times 10^{3}$ mol	1
$n(\text{dopamine})_{\text{titration}} = (1/1) \times n(HC\ell) = 6.525 \times 10^{3}$ mol	1
$n(\text{dopamine})_{\text{total}} = (250.0/25.00) \times n(\text{dopamine})_{\text{titration}} = 6.525 \times 10^{2}$ mol	1
n = m/M, M = m/n M(dopamine) = 10.0 / 6.525×10^{2} = 153.2 g mol^{-1} *(units not required)*	1
M(Empirical Formula) = M($C_8H_{11}NO_2$) = 153.18 153.2 / 153.18 = 1 Therefore Empirical Formula = molecular formula **= $C_8H_{11}NO_2$**	1
Total	**5**

Question 39 **(19 marks)**

Methyl red is an indicator that exists in two different coloured forms, depending on the pH of the solution. In solutions below pH 4.4 the indicator will produce a red colour; above pH 6.2 the indicator appears yellow. Between these pH value's, an orange colouration will appear.

The conversion between the two forms in aqueous solution is shown below.



Yellow form *Red form*

(a) State why the yellow form of methyl red can be described as the conjugate base of the red form of methyl red. (1 mark)

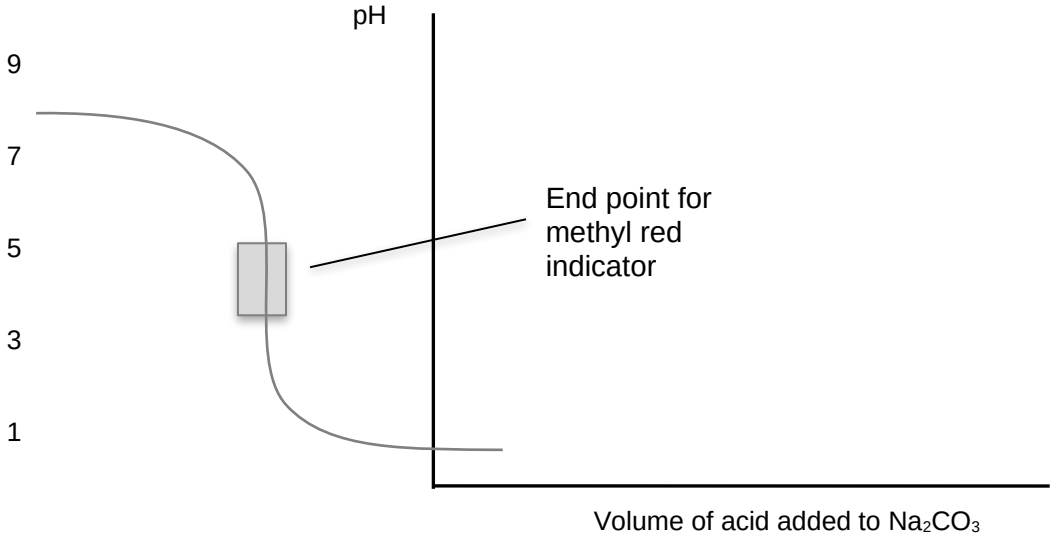
Description	Marks
it accepts a proton from the red form	1
Total	**1**

(b) Using your knowledge of equilibrium and reaction rates, state and explain how the concentrations of the three ions in the reaction above change when alkali is added. (4 marks)

Description	Marks
addition of alkali **reduces** the concentration of hydrogen/hydronium ions $H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$ *or* $H_3O^+(aq) + OH^-(aq) \rightarrow 2\ H_2O(\ell)$ *need equation or state that H_3O^+ react / neutralised by the hydroxide ions to get mark*	1
concentration of the yellow form increases	1
concentration of the red form increases	1
Explanation for above two observations: because the rate of the forward reaction reduces / reverse reaction is favoured	1
Total	**4**

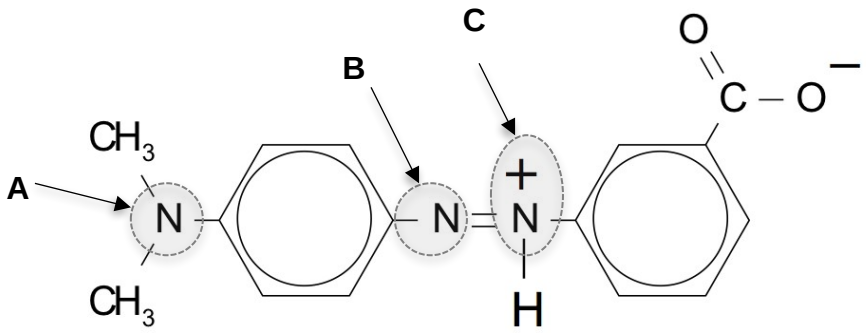
(c) Explain using equations and a graph sketched on the axis below, why methyl red is a suitable indicator for the titration of hydrochloric acid and sodium carbonate solution.

(5 marks)



Description	Marks
equation for the titration: (molecular or ionic) $Na_2CO_3(aq) + 2\ HC\ell\ (aq) \rightarrow 2\ NaC\ell\ (aq) + H_2O(\ell) + CO_2(g)$ *or:* $CO_3^{2-}(aq) + 2\ H^+(aq) \rightarrow Na^+(aq) + H_2O(\ell) + CO_2(g)$	1
carbon dioxide produced makes the equivalence point acidic	1
acidity of carbon dioxide shown by equation: $CO_2(aq) + H_2O(\ell) \rightleftharpoons H_2CO_3(aq)$ *or:* $H_2CO_3(aq) + H_2O(\ell) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$ *or:* $H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$	1
pH curve shows equivalence point below pH 7	1
end point/colour change for methyl red shown on graph or identification/explanation that the end point of the titration must be aligned with the equivalence point of the reaction	1
Total	**5**

(c) In the red form of methyl red, the shape of the bonds around each of the three nitrogen atoms **A**, **B** and **C** varies. One is trigonal planar, one is trigonal pyramidal and one is bent (v-shaped).



Using the valence shell electron pair repulsion (VSEPR) theory, identify the shape around each of the nitrogen atoms, **A**, **B** and **C** and explain your reasoning, using diagrams where appropriate. (9 marks)

Description	Marks
*nitrogen atom **A***	
trigonal pyramidal	1
three bonding pairs, one lone pair	1
shown by diagram	1
*nitrogen atom **B***	
bent (v-shaped)	1
one double bond, one single bond, one lone pair	1
shown by diagram	1
*nitrogen atom **C***	
trigonal planar	1
one double bond, two single bonds, no lone pair	1
shown by diagram	1
Total	**9**

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Question 40 **(16 marks)**

The overall redox equations occurring in the operation (discharging) of three types of commercial electrochemical cells are shown below, along with some information about each cell.

The Dry Cell (Leclanché Cell)

$Zn(s) + 2\ MnO_2(s) + 2\ NH_4^+(aq) \rightarrow Zn^{2+}(aq) + Mn_2O_3(s) + 2\ NH_3(g) + H_2O(\ell)$

The electrolyte used in this cell is a paste containing ammonium ions with a minimum amount of water. The cathode of the cell is made from graphite, which allows electrons to flow through the cathode, but the carbon is not oxidised or reduced in the process.

The Hydrogen Fuel Cell

$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(\ell)$

Hydrogen gas is bubbled through water so that it is in contact with an electrode made of platinum metal. Oxygen is also bubbled through water in contact with another electrode made of platinum metal. The electrodes are connected by an external circuit.

This cell can be recharged by connecting an external voltage to the cell, which reverses the reaction shown above.

The Lead-acid Cell

$Pb(s) + PbO_2(s) + 4\ H^+(aq) + 2\ SO_4^{2-}(aq) \rightarrow 2\ PbSO_4(s) + 2\ H_2O(\ell)$

The electrolyte used in this cell is dilute sulfuric acid. This cell can also be recharged by connecting an external voltage to the cell.

(a) With reference to these equations, compare and contrast the three cells by describing the reactions occurring at the **anodes** of the three cells using the relevant half-equations, comparing the role of the anode and explaining what happens to the ions produced by these anode reactions. (8 marks)

Description	Marks
Up to 3 marks for correct (and balanced) anode reactions	
Dry Cell $Zn(s) \rightarrow Zn^{2+}(aq) + 2\ e^-$	0-3
Fuel Cell $H_2(g) \rightarrow 2\ H^+(aq) + 2\ e^-$	
Lead-acid Cell $Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2\ e^-$	
Up to 3 marks for points of chemistry related to ions	
The Dry Cell • Zinc ions move in the electrolyte towards the carbon cathode	0-3
Fuel Cell • hydrogen ions will be dissolved in the water • reducing the pH of the electrolyte / making the water more acidic • hydrogen ions move in the electrolyte/water towards the carbon cathode	
Lead-acid Cell • lead(II) ions form precipitate with sulfate ions / coat the anode with (insoluble) lead sulfate • lead ions remain close to the anode	
Up to 2 marks for compare and contrast, for example:	
• Lead-acid cell is the only one where solid/precipitate is formed • Fuel cell uses an inert anode (platinum) whereas in the others the anode material (zinc/lead) is oxidised • All reactions produce 2 moles of electrons for each mole of reactant • Fuel cell the hydrogen has to be provided in a flow process, whereas the dry cell and the Lead-acid cell do not have to be continuously supplied with 'fuel'/chemicals	0-2
Total	**8**

(b) The Hydrogen Fuel Cell and the Lead-acid Cell are described as secondary cells because they can be recharged. In order to recharge the cells, the external voltage supplied must be greater than the potential produced by the cells. Use the standard electrode potentials on the Chemistry Data Sheet to calculate which cell would require the highest external voltage during recharging. (5 marks)

Description	Marks
Hydrogen Fuel Cell	
$2\ H^+(aq) + 2\ e^- \rightleftharpoons H_2(g)$ $E° = 0.00$ V	
Identification of correct cathode/reduction half-equation $O_2(g) + 4\ H^+(aq) + 4\ e^- \rightleftharpoons 2\ H_2O(\ell)$ $E° = +0.40$ V	1
Overall cell potential = + 0.40 V - (0.00) **= + 0.40 V**	1
Lead-acid Cell	
$PbSO_4(s) + 2\ e^- \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$ $E° = -0.36$ V	
Identification of correct cathode/reduction half-equation $PbO_2(s) + 2\ SO_4^{2-}(aq) + 4\ H^+(aq) + 2\ e^- \rightleftharpoons 2\ PbSO_4(s) + 2\ H_2O(\ell)$ $E°= +1.69$ V	1
Overall cell potential = + 1.69 V - (- 0.36) **= + 2.05 V**	
Therefore the lead-acid cell will require a higher voltage	1
Total	**5**

(c) Describe **two** reasons why the values calculated from the standard electrode potentials may not give accurate results in part (b) above. (3 marks)

Description	Marks
Limitations of standard electrode potentials *Accept two from:* • assume 1.00 mol L^{-1} solutions • assume standard pressure (100 kPa) • assume 25 °C	0-2
Appropriate link to context of part (b) : Accept one from: • hydrogen and oxygen in the fuel may not be at standard pressure • $[H^+]$ in car battery may be greater than 1.00 mol L^{-1} • $[H^+]$ in fuel cell may be less than 1.00 mol L^{-1} • Temperature may not be 25 °C *or other suitable suggestion*	1
Total	**3**

Question 41 **(14 marks)**

Lawn sand is a mixture of iron compounds (in the form of Fe2+) and sand (mainly SiO2). It is used to kill moss in lawns. An experiment was carried out to determine the percentage of iron in a sample of lawn sand. The method and student's results are shown below.

Chemicals:

sample of lawn sand
oxalic acid dihydrate ($C_2H_2O_4.2H_2O$) (dried in oven)
1.00 mol L-1 sulfuric acid (H_2SO_4)
approximately 0.01 mol L-1 potassium permanganate ($KMnO_4$) solution
distilled water

<table>
<tr><th>Method Outline</th><th>Student's results and notes</th></tr>
<tr><td>1. Make up 250.0 mL of a standard solution of approximately 0.03 mol L-1 oxalic acid.</td><td>mass of oxalic acid dihydrate ($C_2H_2O_4.2H_2O$) dissolved in 250.0 mL= 0.920 g</td></tr>
<tr><td>2. Titrate the 0.01 mol L-1 potassium permanganate against standard oxalic acid solution to determine its accurate concentration.</td><td>volume of oxalic acid = 25.00 mL
average volume of $KMnO_4$ = 26.1 mL</td></tr>
<tr><td>3. Weigh out approximately 10 g of the lawn sand and dissolve in 100 mL 1.00 mol L-1 sulfuric acid.</td><td>Mass of lawn sand used = 10.21 g</td></tr>
<tr><td>4. Filter and make the filtrate up to 500.0 mL with distilled water in a volumetric flask.</td><td>Filtrate is pale green solution
Residue contains sand and other impurities</td></tr>
<tr><td>5. Titrate a 25.00 mL sample of this solution against the standardised potassium permanganate solution.</td><td>
<table>
<tr><td></td><td colspan="4">Trials</td></tr>
<tr><td></td><td>Rough</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>Final volume (mL)</td><td>18.10</td><td>35.50</td><td>18.55</td><td>35.90</td></tr>
<tr><td>Initial volume (mL)</td><td>0.00</td><td>18.10</td><td>1.10</td><td>18.55</td></tr>
<tr><td>Titre (mL)</td><td>18.1</td><td>17.40</td><td>17.45</td><td>17.35</td></tr>
</table>
</td></tr>
</table>

The relevant half-equations are shown below:

$C_2H_2O_4(aq) \rightarrow 2\ CO_2(g) + 2\ H^+(aq) + 2\ e^-$

$MnO_4^-(aq) + 8\ H^+(aq) + 5\ e^- \rightarrow Mn^{2+}(aq) + + 4\ H_2O(\ell)$

$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$

Calculate the percentage by mass of iron in the lawn sand.

Description	Marks
making the standard solution of oxalic acid	
m(C2H2O4.2H2O) = 0.931 g n(C2H2O4.2H2O) = m/M = 0.920 / 126.068 = 7.298 × 103 mol	1
c(C2H2O4) = n/V = 7.298 × 103 / 0.250 = 0.02919 mol L-1	1
standardising the KMnO4	
n(C2H2O4) = c × V = 0.02919 × 0.025 = 7.298 × 104 mol	1
$2\ MnO_4^- + 6\ H^+ + 5\ C_2H_2O_4 \rightarrow 2\ Mn^{2+} + 8\ H_2O + 10\ CO_2$	1
n(MnO4–) = (2/5) × n(C2H2O4) = (2/5) × 7.298 × 104 = 2.919 × 104 mol	1
c(MnO4–) = n / V = 2.919 × 104 / 0.0261 = 0.01118 mol L-1	1
carrying out the titration	
V(MnO4–) = (17.4 + 17.45 + 17.35) / 3 = 17.40 mL	1
n(MnO4–) = c × V = 0.01118 × 0.0174 = 1.946 × 104 mol	1
$MnO_4^- + 8\ H^+ + 5\ Fe^{2+} \rightarrow 2\ Mn^{2+} + 4\ H_2O + 5\ Fe^{2+}$	1
n(Fe2+)titration = (5/1) × n(MnO4–) = (5/1) × 1.946 × 104 = 9.730 × 104 mol	1
n(Fe2+)total = (500/25) × n(Fe2+)titration = (500/25) × 9.730 × 104 mol = 0.01946 mol	1
conversion to percentage by mass	
m(Fe2+)total = n × M = 0.01946 × 55.85 = 1.087 g	1
%(Fe) = (1.087 / 10.21) × 100 **= 10.6%**	1
correct significant figures (3) in final answer	1

Total	**14**