Year 12 2011

SOLUTIONS

3A/3B Chemistry
Semester 2

Your marks	Marks available
	50
	70
	80
	200

Final mark %

Name: .....

Teacher: (circle your teacher's name) **MR SMITH** **MR LUCARELLI**

MR SANDER **MS SMITH**

Time allowed for this paper
Reading time before commencing work: Ten minutes
Working time for paper: Three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:
- This Question/Answer Booklet
- Multiple Choice Answer Sheet
- Data sheet

To be provided by the candidate:
- Standard items: Pens, pencils, eraser or correction fluid, ruler, highlighter.
- Special items: Calculators satisfying the conditions set by the Curriculum Council for this subject.

IMPORTANT NOTE TO CANDIDATES

- No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Suggested working time	Number of questions available	Number of questions to be attempted	Marks
ONE: Multiple-choice	45 minutes	25	25	50
TWO: Short response	60 minutes	12	12	70
THREE: Extended response	75 minutes	6	6	80
			[Total marks]	200

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2010.* Sitting this examination implies that you agree to abide by these rules.

2. Answer the questions according to the following instructions.

   Section One: 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.

   Sections Two and Three: Write your answers in this Question/Answer Booklet.

3. When calculating numerical answers, show your working or reasoning clearly unless instructed otherwise.

4. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

5. 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.

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SECTION 1: 25 multiple choice questions (50 marks 25 %)

Answer ALL questions in Part 1 on the Separate Multiple Choice Answer Sheet provided, using a 2B pencil. Each question in this part is worth 2 marks.

1. Which of the following elements has the highest second ionisation energy?

   (a) Calcium
   (b) Magnesium
   (c) Potassium
   (d) Sodium

2. An element, E, is able to react to form both ionic and covalent compounds. How many valence electrons would its atoms most likely possess?

   (a) 1
   (b) 2
   (c) 7
   (d) 8

3. In which of the following pairs of atomic species is the first species larger than the second species?

   (a) sodium ion sodium atom
   (b) oxide ion sulfide ion
   (c) calcium atom magnesium ion
   (d) potassium ion potassium atom

4. Three of the following species have the same number of protons. Which has the different number of protons?

   (a) carbonium ion CH_3^+
   (b) neon ion Ne^+
   (c) fluoride ion F^-
   (d) amide ion NH_2^-

5. Which of the following statements about graphite and silicon dioxide is true?

   (a) Both have atoms bonded together by sharing electrons.
   (b) Both have delocalised electrons.
   (c) Graphite has a very high melting point while silicon dioxide has a very low melting point.
   (d) Silicon dioxide is ionic while graphite is metallic.

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6. What is the shape of a water molecule?

(a) Linear
(b) Bent (V–shape)
(c) Pyramidal
(d) Tetrahedral

7. Which type of bonding is not present in solid hydrogen chloride?

(a) covalent
(b) dipole – dipole
(c) dispersion force
(d) hydrogen bonding

8. The boiling points of a family of trihalomethanes (CHX_3) are listed below.

Tetrafluoromethane	CHF_3	–89 ^oC
Tetrachloromethane	$CHCl_3$	61 ^oC
Tetrabromomethane	$CHBr_3$	150 ^oC
Tetraiodomethane	CHI_3	330 ^oC

The increase in boiling points moving down the list is due to an increase in the strength of:

(a) covalent bonding.
(b) dispersion forces.
(c) dipole-dipole bonding.
(d) hydrogen bonding.

9. Which of the following saturated solutions has the highest concentration of ions?

(a)	barium hydroxide	$Ba(OH)_2$
(b)	calcium phosphate	$Ca_3(PO_4)_2$
(c)	silver sulfate	Ag_2SO_4
(d)	zinc carbonate	$ZnCO_3$

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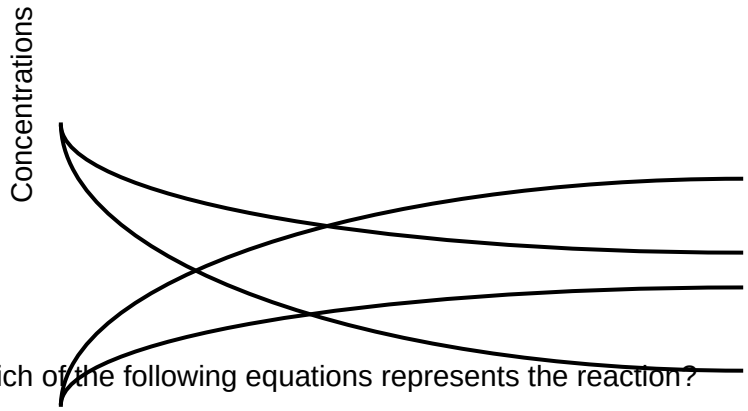
10. Two gases are mixed in a sealed flask. They react to produce two new gases. However, the reaction is reversible and soon equilibrium is established. The following graph shows the concentrations of the four gases as equilibrium is established.



Which of the following equations represents the reaction?

(a) Cl_2O_7 + 2 CO ⇌ Cl_2O_5 + 2 CO_2

(b) N_2O_5 + SO_2 ⇌ N_2O_4 + SO_3

(c) N_2O + 2 ClO_2 ⇌ N_2O_5 + Cl_2

(d) 2 PH_3 + 3 COF_2 ⇌ 2 PF_3 + 3 CH_2O

11. Molybdenum (III) chloride, $MoCl_3$, is a yellow solid. When dissolved in water the molybdenum ions reacts reversibly with chloride ions to form hexachloromolybdenum (III) ions, which are blue.

$$Mo^{3+}(aq) + 6\,Cl^{-}(aq) \rightleftharpoons MoCl_6^{3-}(aq) + 33\ kJ$$

yellow blue

As a result of the equilibrium the solution appears green. Which of the following procedures will cause the green solution to turn blue?

I. Bubbling hydrogen chloride gas through the solution
II. Adding a solution of silver nitrate
III. Heating the solution
IV. Adding a suitable catalyst to increase the forward reaction rate

(a) I only

(b) I and IV only

(c) II and III only

(d) II, III and IV only

12. Arsenine (AsH_3) can be produced by the hydrogen reduction of tetraarsenic hexoxide. The reaction is exothermic and reversible.

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$$3\ As_4O_6\ (s) + 36\ H_2\ (g) \rightleftharpoons 12\ AsH_3\ (g) + 18\ H_2O\ (g) + 125\ kJ$$

Which of the following conditions will maximise the rate of forward reaction?

I. Continuously adding hydrogen at high pressure
II. Maintaining a high temperature
III. Continuously cooling the mixture
IV. Continuously removing the arsenine

(a) I and II
(b) II and III
(c) I and III
(d) I, III and IV

13. Which of the following ions does not have a conjugate base?

(a) CH_3COO^-
(b) HCO_3^-
(c) NH_4^+
(d) H_3O^+

14. Water can act as an acid or as a base. In which of the following reactions is water acting as an acid?

I. $H_2O + NH_4^+ \rightarrow H_3O^+ + NH_3$
II. $H_2O + HPO_4^{2-} \rightarrow OH^- + H_2PO_4^-$
III. $H_2O + SO_4^{2-} \rightarrow OH^- + HSO_4^-$
IV. $H_2O + HCl \rightarrow H_3O^+ + Cl^-$

(a) I only
(b) I and IV only
(c) II and III only
(d) IV only

15. Three of the following solutions have a pH of very close to 7. One has a pH of close to 4. Which is the pH 4 solution?

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(a) ammonium acetate NH_4CH_3COO

(b) ammonium chloride NH_4Cl

(c) ammonium phosphate $(NH_4)_3PO_4$

(d) sodium bromide NaBr

16. In which of the following species does platinum have the lowest oxidation number?

(a) H_2PtCl_6

(b) $NaPtCl_4$

(c) Pt_2O_3

(d) $PtCr_2O_7$

17. Which of the following metals can be produced by bubbling hydrogen gas through a solution of its chloride?

(a) Copper

(b) Iron

(c) Sodium

(d) Zinc

18. A group of students is designing an electrochemical cell consisting of two half cells joined by a salt bridge. Each of the half cells consists of a metal rod placed in a 1 mol L^{-1} solution of its nitrate. Which of the following pairs of half cells will produce the highest voltage (emf)?

(a) Aluminium in aluminium nitrate solution and iron in iron (II) nitrate solution

(b) Copper in copper (II) nitrate solution and zinc in zinc nitrate solution

(c) Lead in lead (II) nitrate solution and manganese in manganese (II) nitrate solution

(d) Silver in silver nitrate solution and tin in tin (II) nitrate solution

19. Pieces of magnesium buried in the ground and connected to an iron pipe prevent corrosion of the iron. The best explanation for this is that

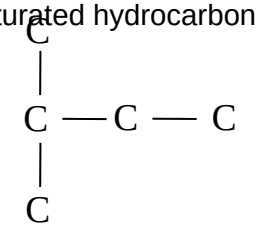
(a) magnesium forms a coat of magnesium hydroxide on the iron.

(b) the magnesium atoms immediately replace atoms of iron that are lost.

(c) a protective coating of Fe^{3+} is left on the iron as electrons flow from the iron to the magnesium.

(d) magnesium is a more reactive metal than iron and it is oxidised in preference to the iron

20. The following structural diagram represents a saturated hydrocarbon. What is the correct (IUPAC) name for the hydrocarbon?



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(a) Dimethyl propane

(b) Ethyl propane

(c) Methyl butane

(d) Pentane

21. Which of the following chlorinated propenes has two geometric (cis-trans) forms?

I. 1 – chloropropene

II. 2 – chloropropene

III. 3 – chloropropene

(a) I only

(b) I and III only

(c) II and III only

(d) III only

22. Which of the following substances is least likely to react with an acidified solution of sodium permanganate?

(a) 1 – propanol

(b) 2 – propanol

(c) Propanal

(d) Propanone

23. One mole of an organic compound, containing only carbon, hydrogen and oxygen, required five moles of oxygen for complete combustion. Four moles of carbon dioxide and four moles of water were produced. What was the formula of the compound?

(a) C_2H_4O

(b) $C_4H_4O_2$

(c) C_4H_8O

(d) $C_4H_8O_2$

24. The following diagram represents part of a polymer chain in a plastic.

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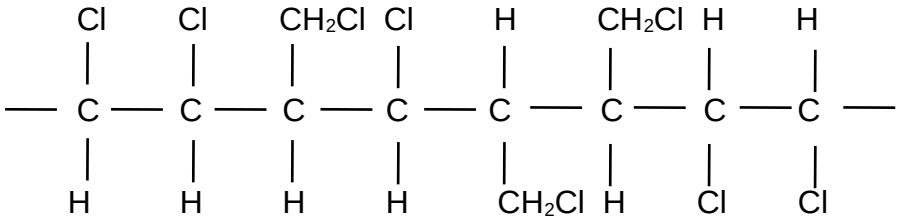

This polymer could be produced from

I. cis – 1,3 – dichloropropene
II. trans – 1,3 – dichloropropene
III. dichloropane
IV. 1,2 - dichloropropene

(a) I or II only
(b) II or IV only
(c) II or IV only
(d) I, II or IV only

25. Which of the following substances will not act as a surfactant (soap / detergent)?

(a) Ammonium stearate (stearate ion = $C_{17}H_{35}COO^-$)
(b) Magnesium stearate (stearate ion = $C_{17}H_{35}COO^-$)
(c) Hexadecylammonium sulfate (hexadecylammonium ion = $C_{16}H_{33}NH_3^+$)
(d) Sodium hexadecylsulfonate (hexadecylsulfonate ion = $C_{16}H_{33}SO_3^-$)

END OF SECTION 1

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SECTION 2 12 questions (70 marks 35 %) Answer ALL questions in the spaces provided.

Spare pages are included at the end of this booklet. They can be used for planning your answers 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.
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Suggested time for this section is 70 minutes.

Question 26 **(4 marks)**

Write equations for the reactions that occur in each of the following procedures.
If no reaction occurs, write 'no reaction'. For full marks, chemical equations should refer only to those species consumed in the reaction and the new species produced. These species may be **ions** [for example, Ag^+], **molecules** [for example NH_3] or **solids** [example $CaCO_3$].

(a) Chlorine gas is bubbled through an acidified solution of hydrogen peroxide. (2 marks)

Equation

$$\mathbf{H_2O_2\,(aq) + Cl_2\,(g) \rightarrow 2\,H^+\,(aq) + 2\,Cl^-\,(aq) + O_2(g)}$$

(b) Potassium permanganate added to butanal. (2 marks)

Equation

$$\mathbf{5\,CH_3CH_2CH_2CHO + 2MnO_4^- + 6H^+ \rightarrow 5\,CH_3CH_2CH_2COOH + 2Mn^{2+} + 3H_2O}$$

Question 27 **(4 marks)**

Write observations for any reactions that occur in the following procedures. In each case describe in full what you would observe, including any

- colours
- precipitates
- gases produced

If no change is observed, you should state this.

(a) Hydrogen peroxide is added to an acidified solution of iron (II) sulfate. (2 marks)

Observation

A colourless solution is added to a pale green solution and the solution turns brown

(b) Copper wire is placed in a solution of nickel chloride. (2 marks)

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Observation

A pink/brown wire is placed in a green solution but no visible change occurs

Question 28 **(4 marks)**

Anions such as hydrogencarbonate (HCO_3^-) and hydrogenphosphate (HPO_4^{2-}) are able to act as bases in aqueous solutions. However, in water hydrogensulfate ion (HSO_4^-) does not act as a base.

Explain these facts. Include equations.

Hydrogencarbonate and hydrogenphosphate ions come from weak acids and so some of the ions will accept protons from water to form the unionised acid forms

HCO_3^- (aq) + H_2O (l) ⇋ H_2CO_3 (aq) + OH^- (aq) acts as a base

HPO_4^- (aq) + H_2O (l) ⇋ $H_2PO_4^-$ (aq) + OH^- (aq) acts as a base 3

HSO_4^- (aq) + H_2O (l) ⇋ H_2SO_4 (aq) + OH^- (aq) does not occur because H_2SO_4 is a strong acid. The HSO_4^- ion does not accept a proton to become the unionised H_2SO_4 molecules. Hydrogensulfate ion can only act as an acid. 1

HSO_4^- (aq) + H_2O (l) ⇋ SO_4^{2-} (aq) + H_3O^+ (aq)

Students may give equations where the anions are reacting with other species, not water. Accept these answers, using discretion.

Question 29 **(4 marks)**

Write the IUPAC name, or draw a structural formula, for the following organic compounds.

	OH

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A secondary alcohol (4 CARBONS)	**$CH_3\,CH\,CH_2\,CH_3$**
$CH_3CH(CH_3)COCH_3$	**3 – methyl – 2 – butanone** **(numbers not required)**
cis – 2 – pentene	**$CH_3\,C(H) = C(H)\,CH_2\,CH_3$**

(b) Consider the following substances whose formula is listed as A to F (4 marks)

A: $HOOC(CH_2)_2COOH$ B: $CH_3CH_2CHOHCH_3$ C: $HO(CH_2)_3OH$

D: CH_3CHCH_2 E: acidified $KMnO_4$ F: CH_3CH_2OH

Which of the above (choosing from letters A to F) either singly, or in combination, would you require for the following changes to occur?

(i) A condensation polymer is obtained. Ans ……**A + C**……...

(ii) An aldehyde is produced. Ans ……**E + F or C**……

(iii) An addition polymer is obtained. Ans……**D…**……

(iv) A ketone is produced. Ans……**B + E**……

Question 30 **(4 marks)**

Describe the overall trend in the first ionisation energies of the elements of the third period of the periodic table. Account for this trend in terms of electrostatic attraction.

The 1st ionisation energy shows a *general increase* in value across the 3rd period due to *the number of protons increasing* uniformaly across the row. This means the *force of attraction between the nucleus and the valency electrons increases* uniformaly. Therefore *more energy is required to overcome this force to remove the outer electron.*

Question 31 **(4 marks)**

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CH_3CH_2COH

Would you expect PROPANOL to be soluble in water? **Yes** 1
Explain your reasoning. You should add to the above diagram.

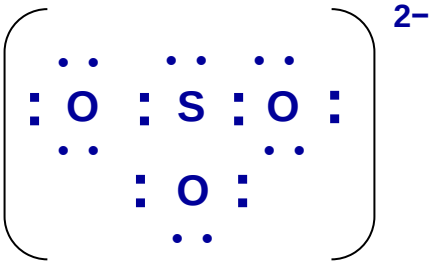
YES

Propanol is polar 1
with the strongly electronegative oxygen atom possessing two lone pairs which are available for hydrogen bonding with water molecules. 1

Question 32 **(6 marks)**

For each species in the following table:

- Draw the structural diagram, representing all valence shell electron pairs as dots (:) or as dashes (—), and
- Indicate the shape (name or sketch) of the species

Species	**Structural diagram** (showing all valence shell electron pairs)	**Shape** (name or sketch)
Methylidyne phosphane HCP	 	**linear**
Sulfite ion SO_3^{2-}		**triangular pyramid**

Question 33 **(8 marks)**

Phosphoric acid (H_3PO_4) is a polyprotic acid.

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(a) List all the anions present (in order of decreasing concentration) in a solution of phosphoric acid (excluding hydroxide).

(1 marks)

$H_2PO_4^-$ > HPO_4^{2-} > PO_4^{3-} 1

(1 marks)

(b) Of these ions, which is the most basic? **PO_4^{3-}** 1

(c) Phosphoric acid is a weak acid. However, it becomes stronger when heated. Explain why. (3 marks)

The ionisation is endothermic and reversible 1

H_3PO_4 + heat ⇋ $H_2PO_4^-$ + H^+ 1

Heating causes a shift to the right, producing a greater concentration of H^+

Strength of an acid is related to the extent (proportion) of ionisation 1

(d) Is propanoic acid (CH_3CH_2COOH) a polyprotic acid? **NO** 1
Explain why. (3 marks)

Only the H in the COOH is acidic 1

The other H atoms are bonded to carbon and do not ionise 1

Question 34 **(4 marks)**

Dodecane can be catalytically cracked to produce lower molecular weight hydrocarbons.

$$C_{12}H_{26}\ (g) + 725\ kJ \rightleftharpoons C_8H_{18}\ (g) + C_4H_8\ (g)$$

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In a laboratory experiment a reaction vessel, whose volume can be changed, contains an equilibrium mixture of all three gases, and 40% of the mixture is dodecane.
The volume is now decreased. The temperature is kept constant.

(a) How does this volume decrease affect the two reaction rates? Explain why.

1 **The decrease in volume increases both reaction rates as all three gases are now more concentrated,**

1 **allowing more frequent (and successful) collisions between molecules.**

[The reverse reaction rate is increased more than the forward as there are more product molecules reacting]

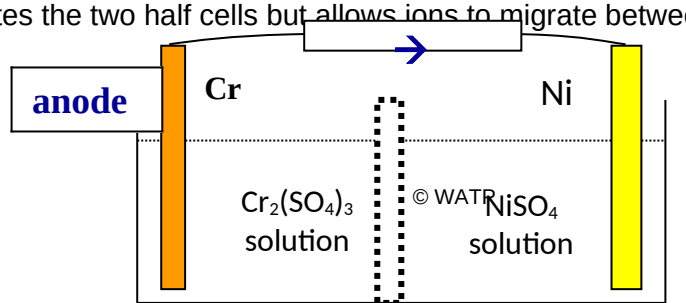
(b) How does this volume decrease affect the percentage composition of the mixture? Explain why.

1 **The percentage of products (octane / butene) decreases and reactant (dodecane) increases**

1 **The volume decrease increases the pressure of the mixture. This causes a shift to the left, which decreases the number of gas molecules, partially compensating for the imposed increase in pressure**

Question 35 **(10 marks)**

The following diagram represents an electrochemical cell based on chromium and nickel. A porous barrier separates the two half cells but allows ions to migrate between them.



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(a) Write the equation for the reaction that occurs. (2 marks)

$2\ Cr\ (s) + 3\ Ni^{2+}\ (aq) \rightarrow 2\ Cr^{3+}\ (aq) + 3\ Ni\ (s)$

(b) On the diagram, label the electrode that is the anode. (1 mark)

(c) Draw an arrow in the box provided to show the direction of the electron flow in the wire. (1 mark)

(d) What emf (voltage) will be generated? (Assume 1 mol L^{-1} concentrations.) (1 mark)

(- 0.26) + (- (- 0.73)) = + 0.47 V

(e) Which metal cations (positive metal ions) will migrate through the porous barrier? (1 mark)

Cr^{3+}

(f) List TWO changes that will be observed. (2 marks)

Cr electrode becomes thinner Ni electrode becomes thicker (Ni coating forms)

Chromium sulphate solution becomes darker green

Nickel sulphate solution becomes lighter green

(g) What will be observed if the porous barrier is removed and the solutions become mixed? (2 marks)

Cr electrode starts to dissolve and a coating forms on it (as nickel deposits on it)
Nickel electrode stops becoming thicker (as there is now direct reaction between nickel ion and chromium)
Current now stops (assuming an ammeter or globe in the circuit)

Question 36 **(8 marks)**

The inside surface of copper frying pans used for cooking foods such as eggs can develop a black coating due to the formation of copper (II) sulfide. These blackened pans can be restored by adding an electrolytic solution such as sodium chloride and placing aluminium foil in the pan. The aluminium foil is held down so that it makes good contact with the copper surface. This method does not remove any of the copper from the pan. The two half reactions that occur are:

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$CuS\ (s) + 2\ e^- \rightarrow Cu + S^{2-}$

$Al\ (s) \rightarrow Al^{3+} + 3\ e^-$

The by-product of this process is aluminium sulfide.

(a) Write an equation for the net redox reaction. (2 marks)

$3\ CuS + 2\ Al \rightarrow 3\ Cu + 2Al^{3+} + 3S^{2-}$ or

$3\ CuS + 2\ Al \rightarrow 3\ Cu + Al_2S_3$

(b) Why must the aluminium foil be touching the copper surface? (2 marks)

To allow electrons to move from the aluminium to the copper sulphide coating as elecrtons do not move through the solution

(d) A frying pan has a 0.0525 g coating of copper sulfide. What mass of aluminium sulfide will be formed as the copper is restored? (4 marks)

$3\ CuS + 2\ Al \rightarrow 3\ Cu + Al_2S_3$

n (CuS) = m / M = 0.0525 / 95.61 = 0.0005491 mol

$n\ (Al_2S_3)$ = 1/3 n(CuS) = 1/3 x 0.0005491 = 0.0001830 mol

$m\ (Al_2S_3)$ = n M = (0.0001830)(150.14) = 0.0275 g 2.75×10^{-2} g

Question 37 **(7 marks)**

Explain each of the following facts about reactions between acids and metals. Include equations.

(a) Zinc reacts with hydrochloric acid, but copper does not. (4 marks)

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Cu^{2+} + 2e → Cu + 0.34

$2\ H^+$ + 2e → H_2 + 0.00 V 2

Zn^{2+} + 2e → Zn – 0.76 V

Cu + $2\ H^+$ → Cu^{2+} + H_2 emf = – 0.34 V will not go

Zn + $2\ H^+$ → Zn^{2+} + H_2 emf = + 0.76 V will go 2

(b) Copper reacts with nitric acid and a gas is produced. The gas is not hydrogen. (3 marks)

From above, Cu will not produce hydrogen, HOWEVER ….. 1

NO_3^- + $2\ H^+$ + e ⇄ NO_2 (g) + H_2O + 0.79 V

Cu^{2+} + 2e ⇄ Cu + 0.34 V

$2\ NO_3^-$ + $4\ H^+$ + Cu ⇄ $2\ NO_2$ (g) + $2\ H_2O$ + Cu^{2+} emf = + 0.45V 1

So Cu will react with nitric acid to produce nitrogen dioxide gas 1

End of Section 2

Section 3 Extended answer 40% (80 Marks)

This section contains six (6) questions Answer ALL questions in the spaces provided.

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Suggested time for this section is 70 minutes.

Question 38 **(15 marks)**

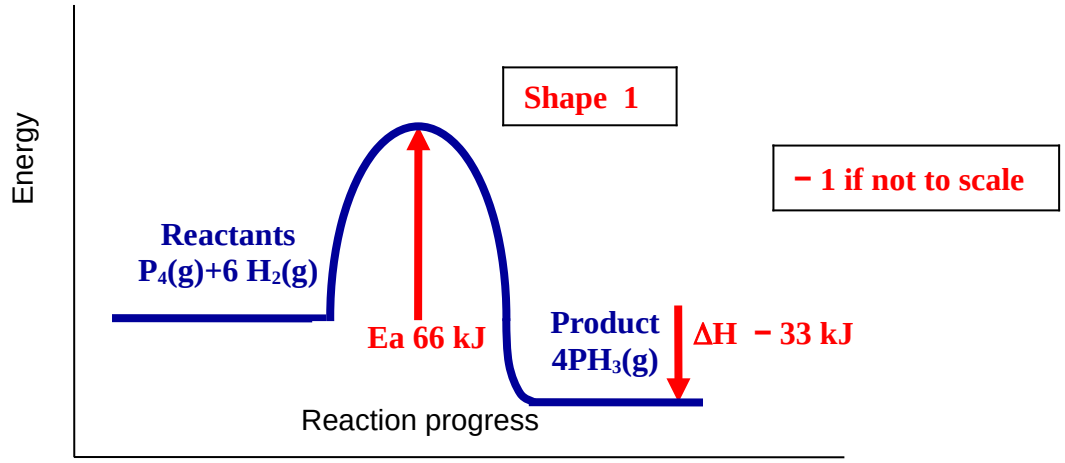
Phosphine (PH_3) is a gas that could be produced by bubbling hydrogen gas through molten phosphorus.

The reaction is reversible P_4 (l) + 6 H_2 (g) ⇌ 4 PH_3 (g) + 33 kJ

Activation energy = 66 kJ

(a) Draw a labelled energy profile graph to represent the process. (4 marks)
Indicate clearly the reactants, products, activation energy and enthalpy change.

½ ½ 1 1



(b) Would a high temperature, or a low temperature, be used in the process? (3 marks)
Explain why.

Marks only for explanation

1 **High temperature favours fast reaction, but also favours shift left [Le Chatelier – uses up some of added heat]**

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1 **Low temperature favours shift right, but reaction will be slow**

1 **High temperature and low temperature are in conflict**
Compromise temperature will be used to maximise yield

(c) Would a high pressure, or a low pressure, be used in the process? Explain why. (3 marks)

Marks only for explanation

1 **High pressure gives a fast reaction rate as hydrogen is a gas**

1 **High pressure also favours shift right**

1 **as this reduces the number of gas molecules, and compensates for the increased pressure**

(d) If the process is only 70.0% efficient what mass of phosphorus would be needed to produce 4500 kL of phosphine (stored at 3.55 atmospheres pressure in cylinders at 30.0 ^{o}C)? (5 marks)

P V = n R T

2 **$n(PH_3) = PV/RT = (3.55 \times 101.3)(4.5 \times 10^6) / (8.315)(303.1) = 642099$ mol**

1 **$n(P_4) = \frac{1}{4}\, n(PH_3) = \frac{1}{4} \times 642099 = 160524$ mol**

1 **$m(P_4) = n M = (160524)(4 \times 30.97)$**

$= 19885811$ g = 19.886 tonne (if process is 100% efficient)

1 **For 70% efficiency more P_4 is needed = 19.886 x 100/70 = 28.4 tonne**

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Question 39 **(10 marks)**

A swimming pool holds 250 cubic metres of water. The owner tests the water and finds its hydroxide ion concentration, $[OH^-]$, is 5.55×10^{-5} mol L^{-1}. (1 cubic metre = 1000 L)

(a) What is the pH of the pool water? (4 marks)

$[H^+] = 10^{-14} / [OH^-] = 10^{-14} / 5.55 \times 10^{-5} = 1.802 \times 10^{-10}$ mol L^{-1} 2

$pH = -\log [H^+] = -\log (1.802 \times 10^{-10}) = 9.74$ 2

(b) Thinking the pH is too low, the owner adds to the water 3.00 kg of caustic soda (NaOH). The water pump ensures that the caustic soda dissolves and becomes evenly mixed in the pool.

What is the new pH of the water? (6 marks)

$n(OH^-)$ initially in the pool = c V = $(5.55 \times 10^{-5})(250\,000)$ = 13.875 mol 1

$n(OH^-)$ added = n(NaOH) = m / M = 3000 / 39.99 = 75.004 mol 1

$n(OH^-)$ total in pool = 75.004 + 13.875 = 88.879 mol 1

now $[OH^-]$ = n / V = 88.875 / 250 000 = 3.556×10^{-4} mol 1

$[H^+] = 10^{-14} / [OH^-] = 10^{-14} / 3.556 \times 10^{-4} = 2.812 \times 10^{-11}$ mol L^{-1} 1

$pH = -\log [H^+] = -\log (2.812 \times 10^{-11}) = 10.55$ 1

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Question 40 **(13 marks)**

An organic compound containing only **carbon, hydrogen, oxygen and nitrogen** is analysed by the following steps:

- 1.473 g is burned in oxygen, converting the carbon to 2.515 g of carbon dioxide and the hydrogen to 1.158 g of water.
- Another 1.473 g is treated so that the nitrogen is oxidized to 0.6573 g of nitrogen dioxide (NO_2).
- When vaporized 1.473 g of the compound occupies 313 mL at 76.0 kPa pressure and 127 ^oC.

(a) What is the empirical formula of the compound? (10 marks)

(b) What is its molecular formula? (3 marks)

n (C) = n(CO_2) = m / M = 2.515 / 44.01 = 0.057146

m (C) = n M = (0.057146)(12.01) = 0.68632 2

n (H) = 2 n(H_2O) = 2 m / M = (2 x 1.158) / 18.016 = 0.12855

m (H) = n M = (0.12855)(1.008) = 0.12958 2

n (N) = n(NO_2) = m / M = 0.6573 / 46.01 = 0.014286

m (N) = n M = (0.014286)(14.01) = 0.20015 2

m (O) = 1.473 – (mC + mH + mN)

= 1.473 – (0.68632 + 0.12958 + 0.20015)

= 0.45695

n (O) = m / M = 0.45695 / 16.00 = 0.02856 2

	C	H	N	O
mol	0.057146	0.12855	0.014286	0.02856
÷ smallest	4	9	1	2

Empirical formula is $C_4 H_9 N O_2$ 2

P V = n R T

n = P V / R T = (76.0)(0.313) / (8.315)(400.1) = 0.00715

That is, 1.473 g = 0.00715 mol

n = m / M so M = m / n = 1.473 / 0.00715 = 206 2

Emp formula mass = 48 + 9 + 14 + 32 = 103

Mol formula mass = 206 = 2 x emp formula 1

So formula is $C_8 H_{18} N_2 O_4$

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Question 41 **(13 marks)**

A student wanting to produce ethyl oxalate prepares a mixture of 50.0 g of oxalic acid (HOOCCOOH) and 50.0 g of alcohol (CH_3CH_2OH) in a boiling flask. She adds a few drops of concentrated sulfuric acid and boils the mixture for about an hour.

The equation for the reaction is

$$HOOCCOOH + 2\ CH_3CH_2OH \rightarrow CH_3CH_2OOCCOOCH_2CH_3 + 2\ H_2O$$

(a) What is the function of the sulfuric acid? (1 marks)

Is a catalyst

(b) Determine the limiting reactant. (4 marks)

n (HOOCCOOH) = n / M = 50.0 / 90.036 = 0.55533 1

n (CH_3CH_2OH) = n / M = 50.0 / 46.068 = 1.0854 1

1 mol HOOCCOOH needs 2 x 0.55533 mol CH_3CH_2OH = 1.1107 1

Not enough CH_3CH_2OH provided so CH_3CH_2OH is limiting reactant 1

(c) What mass of ethyl oxalate would be produced? (4 marks)

n ($CH_3CH_2OOCCOOCH_2CH_3$) = ½ x n (CH_3CH_2OH) 1

= ½ x 1.0854 = 0.5427 1

n ($CH_3CH_2OOCCOOCH_2CH_3$) = n M = (0.5427)(146.14) = 79.3 g 1

1

(d) After the mixture has cooled she adds 100 mL of water. Soon she observes that there are two layer of liquid in the flask

(i) Why were there two liquid layers? (2 marks)

The ester (being only slightly polar) is not miscible with the aqueous solution and so forms a separate layer (on top) 2

(ii) Describe how esters could be used to form polymers. (2 marks)

Polyesters are formed 1

Using a di alcohol and di carboxylic acid 1

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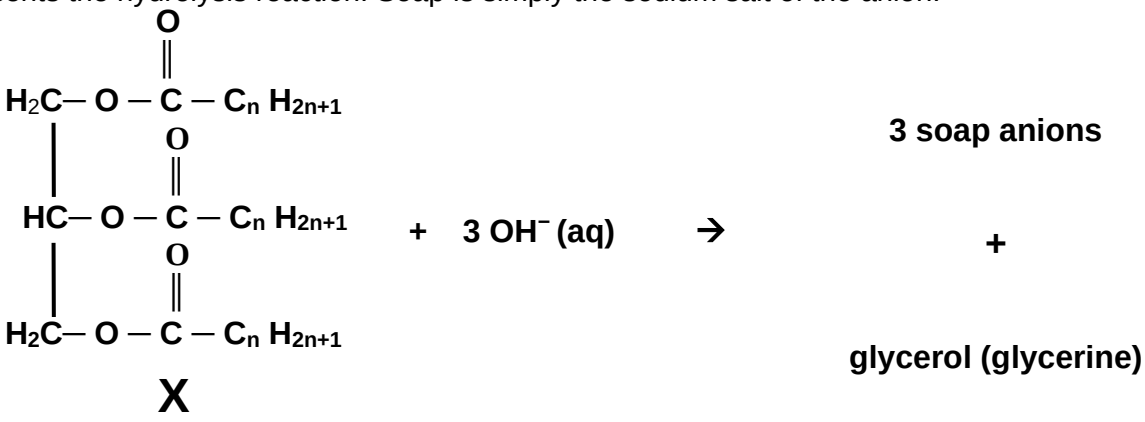
Question 42 **(14 marks)**

Soap can be produced by the alkaline hydrolysis of animal fat. The structure of the fat can be represented by the formula, **X**, below. The number n is large, usually about 16. The equation represents the hydrolysis reaction. Soap is simply the sodium salt of the anion.



(a) What is another name for this process of producing soap? (1 mark)

Saponification (accept hydrolysis)

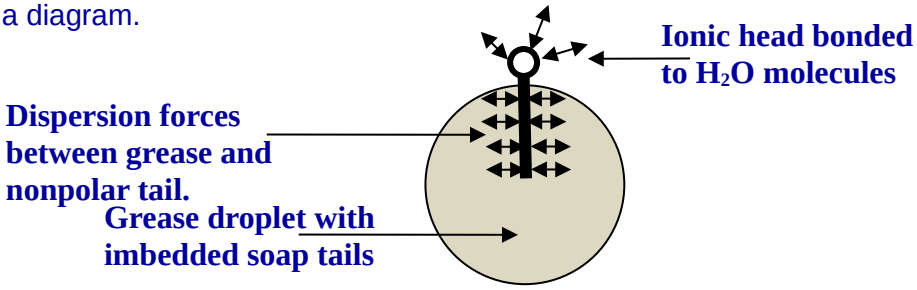
(b) What is the general name for compounds represented by the letter **X**? (1 mark)

Triglycerides (accept fatty acid triesters of glycerol)

(c) Write a formula for soap, substituting numbers for the letter n. (1 mark)

$C_{16}H_{33}COONa$

(d) Why does the hydrocarbon chain (C_nH_{2n+1}) have to be long? (4 mark)
Include a diagram.



2

A long non-polar tail is needed to penetrate deep enough into non-polar grease so that the dispersion forces are strong enough to keep the soap anion attached to the grease while agitation breaks the grease up into tiny micelles. The ionic head is relatively strongly bonded to water molecules by ion-dipole attraction and would be pulled away if the dispersion forces did not keep the tail in the grease.. A short tail has less molecular contact with the grease molecules, resulting in weaker dispersion forces.

2

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(e) When n = 16 in the formula C_nH_{2n+1} the molecular weight of the fat is 848.54.
What mass of sodium hydroxide is needed to convert 1 tonne of fat into soap?
[1 tonne = 1000 kg] (4 mark)

Fat + 3 NaOH → 3 soap anions 1

n (fat) = m / M = 1 000 000 / 848.54 = 1178.5 1

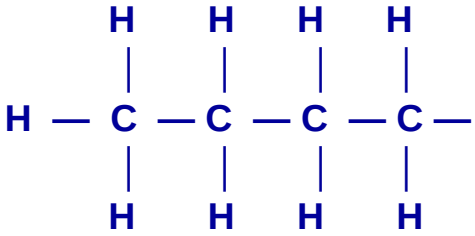
n (NaOH) required = 3 x n (fat) = 3 x 1178.5 = 3535.5 1

n (NaOH) = n M = 3535.5 x 39.998 = 141412 g = 141 kg 1

(f) The hydrocarbon chain represented by the formula C_nH_{2n+1} is a saturated alkyl group. Health professionals are encouraging us to use vegetable oils that are unsaturated or polyunsaturated.

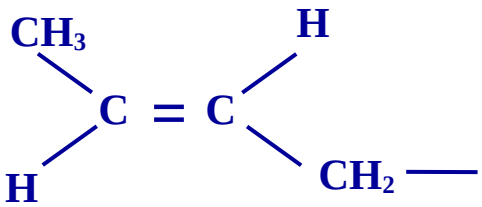
(i) Show that the chain represented by the formula C_nH_{2n+1} is saturated. (2 marks)
Include a diagram of a chain that has 4 carbon atoms.

Saturated means only single bonds between the carbon atoms
A chain with that formula (eg; C_4H_9) cannot have any multiple bonds; only single bonds 1



1

(ii) We are also being encouraged to use less trans-unsaturated oils. (1 mark)
Draw a structure that represents a trans-unsaturated hydrocarbon alkyl group.



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Question 43 **(15 marks)**

A jar containing a pale pink powder is labelled *commercial grade manganese (II) sulfate* $MnSO_4$. A chemist needs to know its percentage by mass purity. He decides to analyse it by utilizing the reaction between hydrogen peroxide and manganese ion. The manganese ions are converted into a black precipitate of manganese (III) oxide. The black oxide quickly settles to the bottom of the conical flask. The equation for the reaction is

$$H_2O_2 + 2\,Mn^{2+} + H_2O \rightarrow Mn_2O_3 + 4\,H^+$$

The end point is taken to be when the final drop of hydrogen peroxide no longer produced a black precipitate.

The chemist dissolved 2.000 g sample of the impure manganese (II) sulfate in water in a 100 mL volumetric flask. He then pipetted 25.00 mL of this solution and diluted it to 250 mL in another volumetric flask.

Next, he titrated 20.00 mL aliquots of the diluted manganese (II) sulfate solution against 0.002211 mol L^{-1} hydrogen peroxide solution. The average titre required was 46.55 mL.

(a) How many moles of hydrogen peroxide were consumed in an average titration? (2 marks)

$n(H_2O_2) = c\,V = (0.002211)(0.04655)$ 1

$= 0.000102922$ mol [1.03×10^{-4}] 1

(b) How many moles of manganese (II) ions were oxidised in an average titration? (2 marks)

$n(Mn^{2+}) = 2 \times n(H_2O_2)$ 1

$= (2)(0.000102922) = 0.000205844$ mol [2.06×10^{-4}] 1

(c) How many moles of manganese (II) sulfate were present in the impure sample? (3 marks)

$n(MnSO_4) = n(Mn^{2+}) \times 250 / 20 \times 100 / 25$ 1

$= 0.000205844 \times 250 / 20 \times 100 / 25$ 1

$= 0.0102922$ mol [1.03×10^{-2}] 1

(d) What was the percentage purity of the commercial manganese (II) sulfate? (3 marks)

$m(MnSO_4) = n\,M = (0.0102922)(151)$ 1

$= 1.554$ g [1.55 g]

Percentage purity = mass $MnSO_4$ / sample mass x 100 2

$= (1.554 / 2.000) \times 100$

$= 77.7$ % 1

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(e) The chemist could also analyse the impure manganese sulfate by dissolving a sample in water, then adding excess hydrogen peroxide solution and finally performing a titration to determine the excess hydrogen peroxide.

(i) Suggest what reagent he could use for the titration.
Include an equation to justify your answer. (4 marks)

The excess peroxide could be titrated against acidified permanganate 2

$5\ H_2O_2 + 2\ MnO_4^- + 6\ H^+ \rightarrow 2\ Mn^{2+} + 5\ O_2 + 8\ H_2O$ 2

Accept reductants, such as chromium (III), bromide, iodide, iron (II) and oxalic acid

$3\ H_2O_2 + 2\ Cr^{3+} + H_2O \rightarrow Cr_2O_7^{2-} + 8\ H^+$

$H_2O_2 + 2\ Br^- + 2\ H^+ \rightarrow Br_2 + 2\ H_2O$

$H_2O_2 + 2\ I^- + 2\ H^+ \rightarrow I_2 + 2\ H_2O$

$H_2O_2 + HOOCCOOH \rightarrow 2\ CO_2 + 2\ H_2O$

$H_2O_2 + 2\ Fe^{2+} + 2\ H^+ \rightarrow 2\ Fe^{3+} + 2\ H_2O$

(ii) Suggest how the end point of this titration would be determined. (1 mark)

For permanganate in the burette the end point will be when the final drop added from the burette turns the peroxide solution in the flask permanently pink.
For permanganate in the flask the end point will be when the final drop of peroxide solution added from the burette permanently decolorizes the purple colour in the flask.

For the other reagent students may suggest valid end point determinations.

End of paper

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