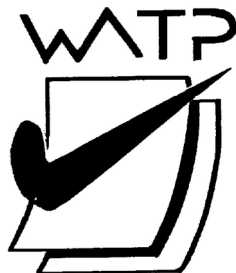


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# **YEAR 12 CHEMISTRY**

## **STAGE 3**

**2011**

## **MARKING GUIDE**

**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.

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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                     $\text{CH}_3^+$   
**(b) neon ion                     $\text{Ne}^+$**   
(c) fluoride ion                     $\text{F}^-$   
(d) amide ion                     $\text{NH}_2^-$
  
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.

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 ( $\text{CHX}_3$ ) are listed below.

Tetrafluoromethane	$\text{CHF}_3$	$-89\text{ }^\circ\text{C}$
Tetrachloromethane	$\text{CHCl}_3$	$61\text{ }^\circ\text{C}$
Tetrabromomethane	$\text{CHBr}_3$	$150\text{ }^\circ\text{C}$
Tetraiodomethane	$\text{CHI}_3$	$330\text{ }^\circ\text{C}$

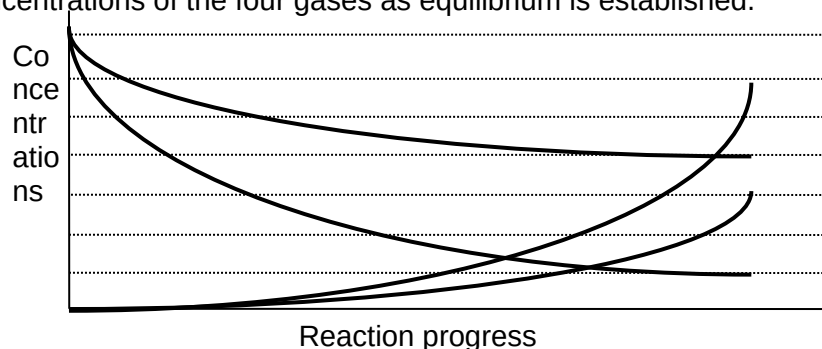
The increase in boiling points moving down the list is due to an increase in the strength of:

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

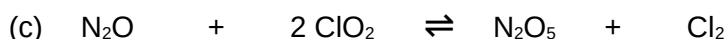
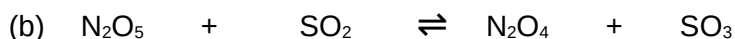
9. Which of the following saturated solutions has the highest concentration of ions?

- (a) barium hydroxide  $\text{Ba(OH)}_2$
- (b) calcium phosphate  $\text{Ca}_3(\text{PO}_4)_2$
- (c) silver sulfate  $\text{Ag}_2\text{SO}_4$
- (d) zinc carbonate  $\text{ZnCO}_3$

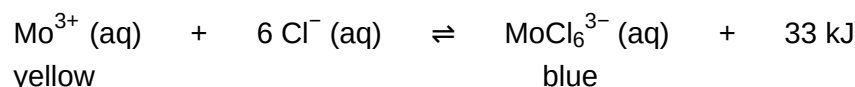
10. Two gases are mixed in a sealed flask. They react to produce two new gases. However, the reaction is reversible and soon equilibrium is established. The following graph shows the concentrations of the four gases as equilibrium is established.



Which of the following equations represents the reaction?

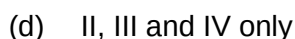


11. Molybdenum (III) chloride,  $\text{MoCl}_3$ , is a yellow solid. When dissolved in water the molybdenum ions reacts reversibly with chloride ions to form hexachloromolybdenum (III) ions, which are blue.

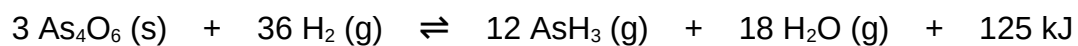


As a result of the equilibrium the solution appears green. Which of the following procedures will cause the green solution to turn blue?

- 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



12. Arsenine ( $\text{AsH}_3$ ) can be produced by the hydrogen reduction of tetraarsenic hexoxide. The reaction is exothermic and reversible.



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)  $\text{CH}_3\text{COO}^-$

(b)  $\text{HCO}_3^-$

(c)  $\text{NH}_4^+$

(d)  $\text{H}_3\text{O}^+$

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

- I.  $\text{H}_2\text{O} + \text{NH}_4^+ \rightarrow \text{H}_3\text{O}^+ + \text{NH}_3$
- II.  $\text{H}_2\text{O} + \text{HPO}_4^{2-} \rightarrow \text{OH}^- + \text{H}_2\text{PO}_4^-$
- III.  $\text{H}_2\text{O} + \text{SO}_4^{2-} \rightarrow \text{OH}^- + \text{HSO}_4^-$
- IV.  $\text{H}_2\text{O} + \text{HCl} \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^-$

(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?

- (a) ammonium acetate  $\text{NH}_4\text{CH}_3\text{COO}$
- (b) ammonium chloride  $\text{NH}_4\text{Cl}$
- (c) ammonium phosphate  $(\text{NH}_4)_3\text{PO}_4$
- (d) sodium bromide  $\text{NaBr}$

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

- (a)  $\text{H}_2\text{PtCl}_6$
- (b)  $\text{NaPtCl}_4$
- (c)  $\text{Pt}_2\text{O}_3$
- (d)  $\text{PtCr}_2\text{O}_7$

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

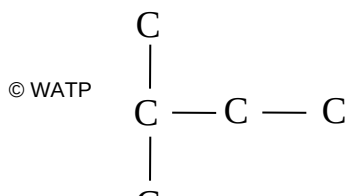
18. A group of students is designing an electrochemical cell consisting of two half cells joined by a salt bridge. Each of the half cells consists of a metal rod placed in a  $1 \text{ mol L}^{-1}$  solution of its nitrate. Which of the following pairs of half cells will produce the highest voltage (emf)?

- (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. Which of the following will oxidise quickly in moist air if its surface is scratched, but further oxidation is prevented by the oxide layer that has formed on the surface?

- (a) A sheet of aluminium
- (b) A sheet of galvanised (completely coated with a thin layer of zinc) iron
- (c) A sheet of copper
- (d) A 'tin' can (iron coated completely with a thin layer of tin)

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



- (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

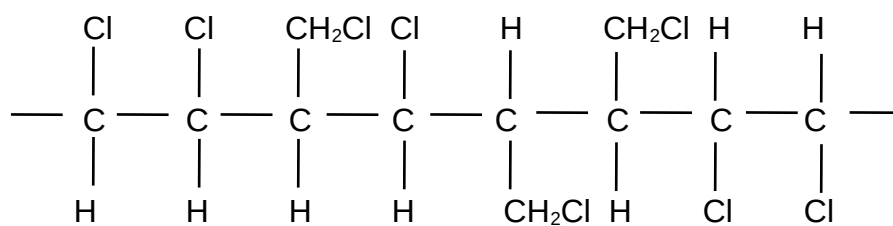
22. Which of the following substances is least likely to react with an acidified solution of sodium permanganate?

- (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.



This polymer could be produced from

- I. cis – 1,3 – dichloropropene
- II. trans – 1,3 – dichloropropene
- III. dichloropropane
- 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 =  $\text{C}_{17}\text{H}_{35}\text{COO}^-$ )

(b) Magnesium stearate (stearate ion =  $\text{C}_{17}\text{H}_{35}\text{COO}^-$ )

(c) Hexadecylammonium sulfate (hexadecylammonium ion =  $\text{C}_{16}\text{H}_{33}\text{NH}_3^+$ )

(d) Sodium hexadecylsulfonate (hexadecylsulfonate ion =  $\text{C}_{16}\text{H}_{33}\text{SO}_3^-$ )

**END OF SECTION 1**



**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.
- Continuing an answer: If you need to use a spare page to continue an answer, indicate in the original answer space where the answer is continued, i.e. state the page number. Write the number of the question(s) that you are continuing to answer at the top of the page.

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,  $\text{Ag}^+$ ], **molecules** [for example  $\text{NH}_3$ ] or **solids** [example  $\text{CaCO}_3$ ].

- (a) Sodium bromide solution is added to an acidified solution of hydrogen peroxide. (2 marks)

Equation



- (b) Solid aluminium oxide is added to nitric acid (2 marks)

Equation

**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)

Observation

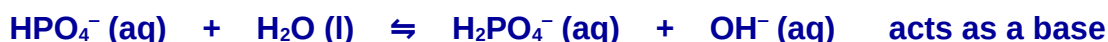
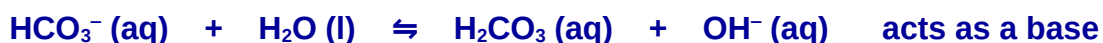
**A pink/brown wire is placed in a green solution but no visible change occurs**

**Question 28****(4 marks)**

Anions such as hydrogencarbonate ( $\text{HCO}_3^-$ ) and hydrogenphosphate ( $\text{HPO}_4^{2-}$ ) are able to act as bases in aqueous solutions. However, in water hydrogensulfate ion ( $\text{HSO}_4^-$ ) 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**



3

$\text{HSO}_4^- (\text{aq}) + \text{H}_2\text{O} (\text{l}) \rightleftharpoons \text{H}_2\text{SO}_4 (\text{aq}) + \text{OH}^- (\text{aq})$  does not occur because  $\text{H}_2\text{SO}_4$  is a strong acid. The  $\text{HSO}_4^-$  ion does not accept a proton to become the unionised  $\text{H}_2\text{SO}_4$  molecules. Hydrogensulfate ion can only act as an acid.

1



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

**Question 29****(4 marks)**

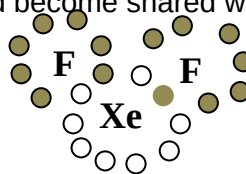
Write the IUPAC name, or draw a structural formula, for the following organic compounds.

A secondary alcohol	$\begin{array}{c} \text{OH} \\   \\ \text{CH}_3\text{CHCH}_2\text{CH}_3 \end{array}$ <p>Many possibilities</p>
3 – methyl – 2 – butanone (numbers not required)	$\text{CH}_3\text{CH}(\text{CH}_3)\text{COCH}_3$
cis – 2 – pentene	$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{CH}_3\text{C} = \text{CCH}_2\text{CH}_3 \end{array}$

**Question 30****(6 marks)**

The noble gases form very few compounds. However, krypton and xenon do form a few unstable compounds, mainly with fluorine and with oxygen. For example, xenon forms xenon difluoride ( $\text{XeF}_2$ ). In this molecule the valence shell of the xenon atom holds 10 electrons (5 electron pairs) because the two electrons of one pair have separated and become shared with two fluorine atoms. Neon and chlorine do not react to form neon chlorides.

Electron dot diagram for xenon difluoride



By referring to electronegativities and ionisation energies explain why a fluorine atom and a xenon atom are able to form a covalent bond, while chlorine and neon do not react.

**1** Fluorine has a very high electronegativity and xenon has a relatively low ionisation energy (valence electrons in fifth shell).

**2** So a xenon atom has a relatively low attraction for its valence electrons, while a fluorine atom has a strong attraction for an extra electron. These factors allow a fluorine atom to pull an electron away from xenon and thus share it to complete its valence shell.

**1** Chlorine is much less electronegative and neon has a very high ionisation energy. So the chlorine atom does not have enough electron attracting power to pull an electron away from a neon atom.

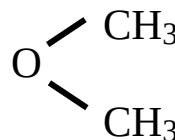
### Question 31

(4 marks)

Dimethyl ether ( $\text{CH}_3\text{OCH}_3$ ) has the structure.

May show water molecules H-bonding to the O  
or  
May show more DME molecules with dispersion forces between them

**2**



Would you expect dimethyl ether to be soluble in water? **Yes / No**

Explain your reasoning. You should add to the above diagram.

**YES**

DME is polar

**1**

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

**NO**

**1**

Even though DME is polar

**1**

the methyl groups can only bond by dispersion force, which are too weak to allow hydrogen bonding between water molecules to be broken

**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)
Methyldyne phosphane  HCP	$\begin{array}{c} \vdots \\ \text{H} : \text{C} : \text{P} : \\ \vdots \\ \text{H} : \text{C} :: \text{P} : \end{array}$	linear
Sulfite ion  $\text{SO}_3^{2-}$		triangular pyramid

### Question 33

(9 marks)

Phosphoric acid ( $\text{H}_3\text{PO}_4$ ) is a polyprotic acid.

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

Write equations to show how you determined this.

(3 marks)



1

Each of the three successive ionization steps produces less of the ions



1



Of these ions, which is the most basic?



1

- (c) Phosphoric acid is a weak acid. However, it becomes stronger when heated.

(3 marks)

Explain why.

**The ionisation is endothermic and reversible**

1



1

**Heating causes a shift to the right, producing a greater concentration of  $\text{H}^+$**

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

1

- (c) Is propanoic acid ( $\text{CH}_3\text{CH}_2\text{COOH}$ ) a polyprotic acid? **NO**

1

Explain why.

(3 marks)

**Only the H in the  $\text{COOH}$  is acidic**

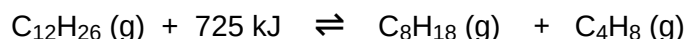
**The other H atoms are bonded to carbon and do not ionise**

1

### Question 34

(4 marks)

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



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**

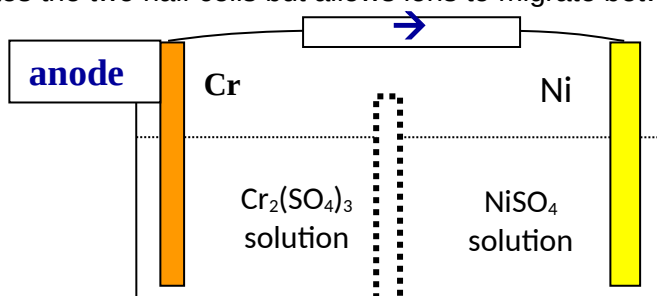
1

**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.



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



- (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  $1 \text{ mol L}^{-1}$  concentrations.) (1 mark)

$$(-0.25) + (-(-0.74)) = +0.49 \text{ V}$$

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



- (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**

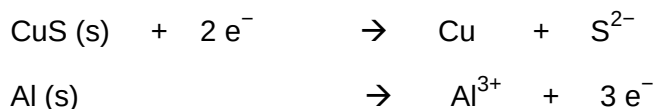
- (g) What will be observed if the porous barrier is removed and the solutions become mixed? (2 marks)

**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)**

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:



1

The by-product of this process is aluminium sulfide.

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



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



- (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)



$$n(\text{CuS}) = m / M = 0.0525 / 95.61 = 0.0005491 \text{ mol}$$

$$n(\text{Al}_2\text{S}_3) = 1/3 n(\text{CuS}) = 1/3 \times 0.0005491 = 0.0001830 \text{ mol}$$

$$m(\text{Al}_2\text{S}_3) = n M = (0.0001830)(150.14) = 0.0275 \text{ g}$$

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)



2



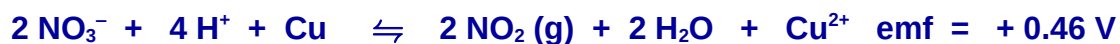
2

- (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



1

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

1

End of Section 2



**This section contains six (6) questions** 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.

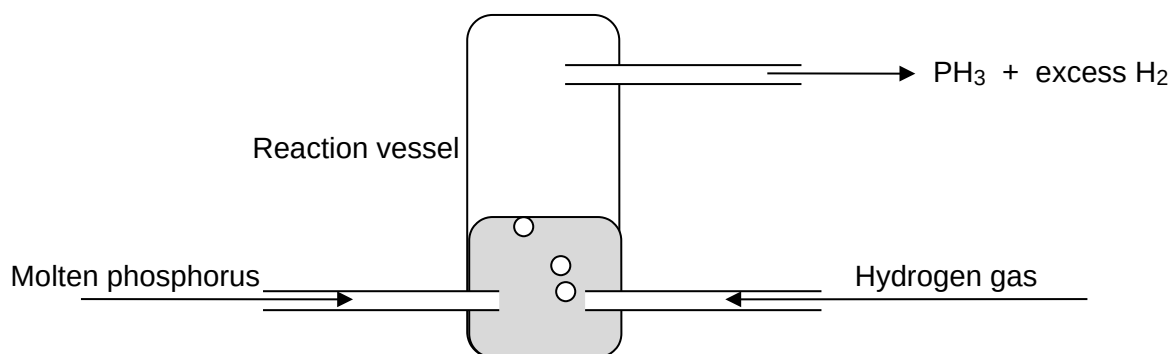
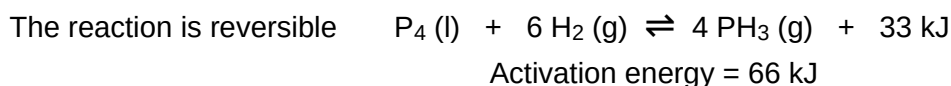
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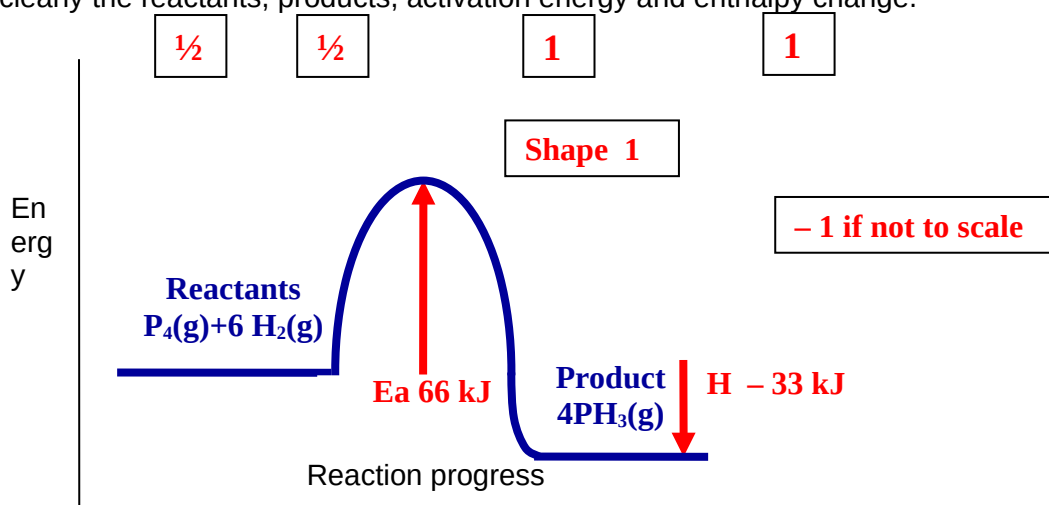
### Question 38

(15 marks)

Phosphine ( $\text{PH}_3$ ) is a gas that could be produced by bubbling hydrogen gas through molten phosphorus.



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



- (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]

**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? (3 marks)  
Explain why.

**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 °C)? (5 marks)

$$P V = n R T$$

**2**  $n(\text{PH}_3) = P V / R T = (3.55 \times 101.3)(4.5 \times 10^6) / (8.315)(303.1) = 642099 \text{ mol}$

**1**  $n(\text{P}_4) = \frac{1}{4} n(\text{PH}_3) = \frac{1}{4} \times 642099 = 160524 \text{ mol}$

**1**  $m(\text{P}_4) = n M = (160524)(4 \times 30.97)$   
 $= 19885811 \text{ g} = 19.886 \text{ tonne (if process is 100% efficient)}$

**1** For 70% efficiency more  $\text{P}_4$  is needed  $= 19.886 \times 100/70 = 28.4 \text{ tonne}$

**Question 39****(10 marks)**

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

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

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

**2**

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

**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)

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

**1**

$$n(\text{OH}^-) \text{ added} = n(\text{NaOH}) = m/M = 3000 / 39.99 = 75.004 \text{ mol}$$

**1**

$$n(\text{OH}^-) \text{ total in pool} = 75.004 + 13.875 = 88.879 \text{ mol}$$

**1**

$$\text{now } [\text{OH}^-] = n/V = 88.875 / 250\,000 = 3.556 \times 10^{-4} \text{ mol}$$

**1**

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

**1**

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

**1**

**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<sub>2</sub>).
- When vaporized 1.473 g of the compound occupies 313 mL at 76.0 kPa pressure and 127 °C.

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

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

$$n(\text{C}) = n(\text{CO}_2) = m / M = 2.515 / 44.01 = 0.057146$$

$$m(\text{C}) = n M = (0.057146)(12.01) = 0.68632$$

2

$$n(\text{H}) = 2 n(\text{H}_2\text{O}) = 2 m / M = (2 \times 1.158) / 18.016 = 0.12855$$

$$m(\text{H}) = n M = (0.12855)(1.008) = 0.12958$$

2

$$n(\text{N}) = n(\text{NO}_2) = m / M = 0.6573 / 46.01 = 0.014286$$

$$m(\text{N}) = n M = (0.014286)(14.01) = 0.20015$$

2

$$m(\text{O}) = 1.473 - (m\text{C} + m\text{H} + m\text{N})$$

$$= 1.473 - (0.68632 + 0.12958 + 0.20015)$$

$$= 0.45695$$

$$n(\text{O}) = m / M = 0.45695 / 16.00 = 0.02856$$

2

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

Empirical formula is C<sub>4</sub> H<sub>9</sub> N O<sub>2</sub>

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

$$n = m / M \text{ so } M = m / n = 1.473 / 0.00715 = 206$$

2

$$\text{Emp formula mass} = 48 + 9 + 14 + 32 = 103$$

$$\text{Mol formula mass} = 206 = 2 \times \text{emp formula}$$

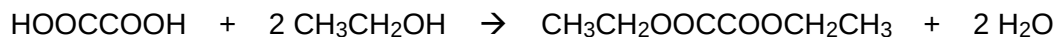
1

So formula is C<sub>8</sub> H<sub>18</sub> N<sub>2</sub> O<sub>4</sub>

**Question 41****(13 marks)**

A student wanting to produce ethyl oxalate prepares a mixture of 50.0 g of oxalic acid (HOCCOOH) and 50.0 g of alcohol (CH<sub>3</sub>CH<sub>2</sub>OH) 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



- (a) What is the function of the sulfuric acid?

(1 marks)

**Is a catalyst**

- (b) Determine the limiting reactant.

(4 marks)

$$n(\text{HOCCOOH}) = n / M = 50.0 / 90.036 = 0.55533$$

1

$$n(\text{CH}_3\text{CH}_2\text{OH}) = n / M = 50.0 / 46.068 = 1.0854$$

1

$$1 \text{ mol HOCCOOH needs } 2 \times 0.55533 \text{ mol CH}_3\text{CH}_2\text{OH} = 1.1107$$

1

**Not enough CH<sub>3</sub>CH<sub>2</sub>OH provided so CH<sub>3</sub>CH<sub>2</sub>OH is limiting reactant**

1

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

(4 marks)

$$n(\text{CH}_3\text{CH}_2\text{OCCCOOCH}_2\text{CH}_3) = \frac{1}{2} \times n(\text{CH}_3\text{CH}_2\text{OH})$$

1

$$= \frac{1}{2} \times 1.0854 = 0.5427$$

1

$$n(\text{CH}_3\text{CH}_2\text{OCCCOOCH}_2\text{CH}_3) = n M = (0.5427)(146.14) = 79.3 \text{ g}$$

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) Suggest a reason for adding water.

(2 marks)

**Sulfuric acid and ethanol and the excess oxalic acid are soluble while the ester is not**

1

**This separates the ester from the other three substances**

1

- (ii) Why were there two liquid layers?

(2 marks)

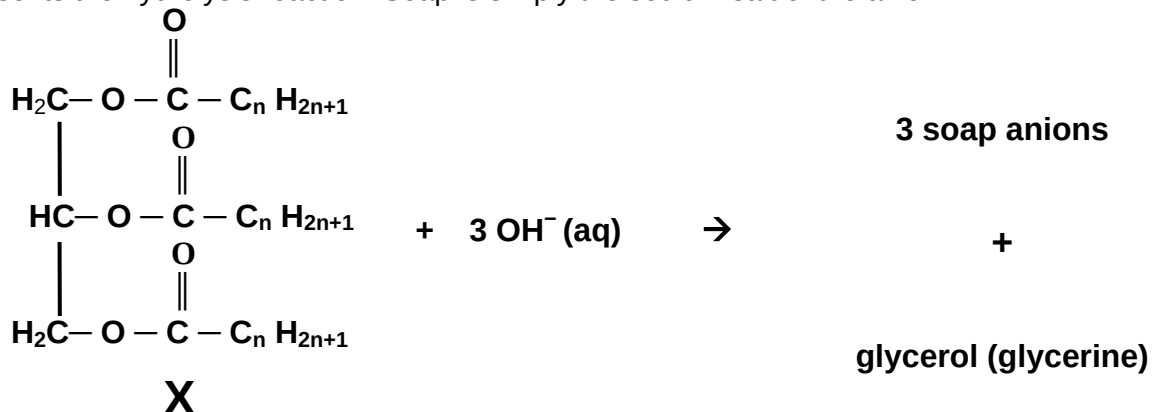
**The ester (being only slightly polar) is not miscible with the aqueous solution and so forms a separate layer (on top)**

2

## 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)**

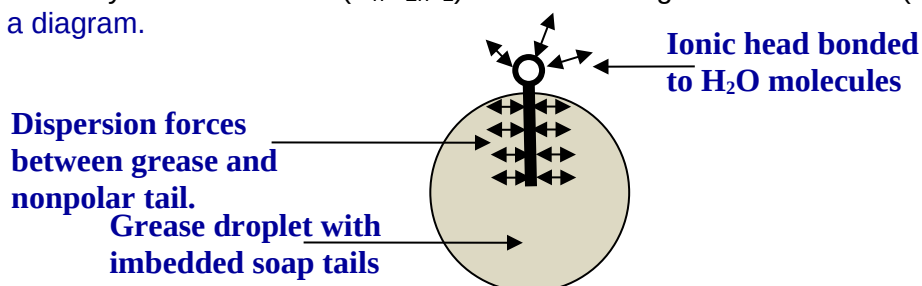
- (b) What is the general name for compounds represented by the letter **X**? (1 mark)

**Triglycerides (accept fatty acid triesters of glycerol)**

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

**$\text{C}_{16}\text{H}_{33}\text{COONa}$**

- (d) Why does the hydrocarbon chain ( $\text{C}_n\text{H}_{2n+1}$ ) 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**

- (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)



1

**$n(\text{fat}) = m / M = 1\,000\,000 / 848.54 = 1178.5$**

1

**$n(\text{NaOH}) \text{ required} = 3 \times n(\text{fat}) = 3 \times 1178.5 = 3535.5$**

1

**$n(\text{NaOH}) = n M = 3535.5 \times 39.998 = 141412 \text{ g} = 141 \text{ kg}$**

1

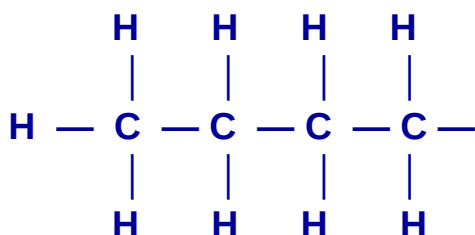
- (f) The hydrocarbon chain represented by the formula  $C_nH_{2n+1}$  is a saturated alkyl group. Health professionals are encouraging us to use vegetable oils that are unsaturated or polyunsaturated.

- (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**

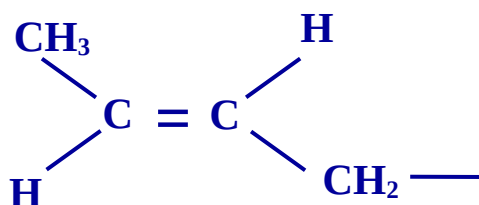
**A chain with that formula (eg;  $C_4H_9$ ) cannot have any multiple bonds; only single bonds**

1



1

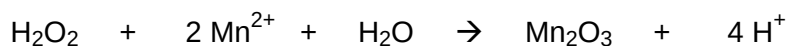
- (ii) We are also being encouraged to use less trans-unsaturated oils. (1 mark)  
Draw a structure that represents a trans-unsaturated hydrocarbon alkyl group.



## Question 43

(15 marks)

A jar containing a pale pink powder is labelled *commercial grade manganese (II) sulfate*  $\text{MnSO}_4$ . 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



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  $0.002211 \text{ mol L}^{-1}$  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)

$$n(\text{H}_2\text{O}_2) = c V = (0.002211)(0.04655)$$

1

$$= 0.000102922 \text{ mol } [1.03 \times 10^{-4}]$$

1

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

$$n(\text{Mn}^{2+}) = 2 \times n(\text{H}_2\text{O}_2)$$

1

$$= (2)(0.000102922) = 0.000205844 \text{ mol } [2.06 \times 10^{-4}]$$

1

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

$$n(\text{MnSO}_4) = n(\text{Mn}^{2+}) \times 250 / 20 \times 100 / 25$$

1

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

1

$$= 0.0102922 \text{ mol } [1.03 \times 10^{-2}]$$

1

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

$$m(\text{MnSO}_4) = n M = (0.0102922)(151)$$

1

$$= 1.554 \text{ g } [1.55 \text{ g}]$$

$$\text{Percentage purity} = \text{mass MnSO}_4 / \text{sample mass} \times 100$$

2

$$= (1.554 / 2.000) \times 100$$

1

$$= 77.7 \%$$



- (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**



**2**

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



- (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**