Comments on Section 2 marking. Stage 3 Chemistry 2010.

General: Follow ALL instructions. ie Read the question.
If an equation is asked for in a question, then an IONIC equation MUST be provided.

Q1. Observations should describe the reactants (anything that occurs during reaction) and the products. ie before during and after

Q2. If NaOH was used then equation needs to be simplified from:
$4MnO_4^- + 32H^+ + 20OH^- \rightarrow 4Mn^{2+} + 26H_2O + 5O_2$ to:
$4MnO_4^- + 12H^+ \rightarrow 4Mn^{2+} + 6H_2O + 5O_2$

Q3. 'Triangular' is not an acceptable name for shape as it could refer to triangular planar OR triangular pyramidal.

Q4. Many students did not follow the instruction 'write the **names'**.
Tetrachloromethane is NOT polar. If named I deducted 2 marks.

Q5. Many students did not follow the instruction 'Include a **labelled** diagram'.
Many students did not mention interaction between the amines and water molecules. ie the need to overcome their own intermolecular attractions, to 'push between' each other.

Q6. Many students did not name the procedure used as titration.
Many students did not follow the instruction to include equations.
Many students simply did not mention the mono-, di- and triprotic nature of the acids.

Q7. Many students did not follow the instruction to include a **labelled** diagram.
Many students mistakenly say that the grease/oil etc 'dissolves' in water – it doesn't actually dissolve, but smaller amounts of the immiscible substance are suspended throughout the water. ie It forms a suspension/colloid of micelles.

Q8. Many students did not follow the instruction to label the anode and cathode.
Follow through marks were only paid if subsequent answers made sense compared to earlier responses.

Q10. Many students did not follow the instruction to include an equation.
Many students only mentioned the potential for reaction with copper, and not tin.

Q11. 2-methyl-1,2-dibromopropane etc were also accepted as a structural isomers of dibromobutane (ie $C_4H_8Br_2$).
Some students still leave **C-H** bonds as **C-** , and lose marks for not indicating that H atoms are attached.

Comments on Section 3 marking. Stage 3 Chemistry 2010.

Question 2:
Some students attributed the change in energy to the change in state ie all solids to liquids and gases.
Part b generally well done.
Many students did not get this reaction correct, considering the information was given in the question and was a simple equation balance.
Part d students did not realise this was a limiting reagent question! If you have two known reacting moles of substances, it must be considered a limiting reagent question. Other students did not realise that phosphorus was diatomic in the equation and as such some used just the molecular mass of phosphorus of 30.97 and not 30.97 x 2.

Question 3:
This was a relatively straight forward empirical formula question with 3 unknowns. Some students could not relate that the number of moles of carbon can be found from the barium carbonate and it is a one to one ratio. A few students forgot to double the number of moles of hydrogen compared to water. Generally students who did well in this question scored full marks. Others were awarded marks for merit and general follow through.

Question 4:
Part a generally well done. Students must label their axes or graph if data is given in the question ie heat and activation energy must have a number label. Although this is considered a sketch, marks were not deducted for the "height of the hill" compared to the level of enthalpy. In WACE exam this may get penalised. Some labelled reactants and products as "reactants and products" and should actually put the reacting and producing species on the sketch.
Part c in a sealed container the conditions that will affect equilibrium are temperature and pressure. For equilibrium, students needed to realise that a lower pressure is needed to favour the yield of products.
Part d needed an informative discussion for four marks. The discussion should mention a catalyst, and compare pressure and temperature conditions of rate vs yield and consider economic/ safety factors. Not one student mentioned Le Chatelier's Principle in their discussion!

Question 5:
Generally well done. The biggest mistake students made was when calculating the density, students used the molecular mass of cerium, rather than the molecular mass of the sulfate compound. The question says find the density of cerium sulfate! ☺

Question 6:
Most students attempted parts a and b quite well. A few students calculated a three week average which was quite surprising!. Students who could not get the ratio in part b may have been awarded one mark for attempting to balance the equations up the page.
Part c did not specify the calculate the mass usage or moles usage, so marks were awarded appropriately. Students need to learn that if you are finding a mass of

reactant in a multi step process and the efficiency is given, somewhere in your response you have to multiply by 100 and divide by 96. Students who factored a ratio of x 1.04 is not accurate enough and marks cannot be awarded.
Part d was not done well by students. Many could not grasp the conversions for calculating the mass of arsenic per tonne of compound. There are a couple of ways of working this question out.

Question 7:
Students lost marks for not drawing the structures of the 4 compounds. If you have to compare the structures, then you have to show their structures! Some students discussed hexan-3-one as having hydrogen bonding, and a few touched on the idea that due to the size of the molecules, the dispersion force might outweigh the hydrogen bonding and dipole interactions in hexan-3-ol and hexan-3-one respectively. This had good merit in response. Students used PHYSICAL tests such as dissolving compounds, testing pH and boiling points to identify the compound, where the question said use CHEMICAL tests and show with CHEMICAL reactions. No merit was given for these physical tests. Some students also did not show the balanced chemical reactions for the chemical tests and subsequently lost marks.

Mt Lawley Senior High School
Semester 2 Examination
Multiple Choice Answer Sheet
Chemistry (Stage 3)

Student Name: Answers

Teacher Name: Meagher / Winter

INSTRUCTIONS:
For each question shade the box to indicate your answer.
Use **only** a blue or black **pen** to shade the boxes.

For example, if b is your answer: ☐a ■b ☐c ☐d

If you make a mistake, place a cross through that square, **do not** erase or use correction fluid and shade your new answer.

For example, if b is a mistake and d is your answer: ☐a ☒b ☐c ■d
Marks will **not** be deducted for incorrect answers.
No marks will be given if more than one answer is completed for any question.

Questions 1-15

1	☐a	☐b	☐c	☐d	6	☐a	☐b	☐c	☐d	11	☐a	☐b	☐c	☐d
2	☐a	☐b	☐c	☐d	7	☐a	☐b	☐c	☐d	12	☐a	☐b	☐c	☐d
3	☐a	☐b	☐c	☐d	8	☐a	☐b	☐c	☐d	13	☐a	☐b	☐c	☐d
4	☐a	☐b	☐c	☐d	9	☐a	☐b	☐c	☐d	14	☐a	☐b	☐c	☐d
5	☐a	☐b	☐c	☐d	10	☐a	☐b	☐c	☐d	15	☐a	☐b	☐c	☐d

Questions 16-25

16	☐a	☐b	☐c	☐d	21	☐a	☐b	☐c	☐d
17	☐a	☐b	☐c	☐d	22	☐a	☐b	☐c	☐d
18	☐a	☐b	☐c	☐d	23	☐a	☐b	☐c	☐d
19	☐a	☐b	☐c	☐d	24	☐a	☐b	☐c	☐d
20	☐a	☐b	☐c	☐d	25	☐a	☐b	☐c	☐d

SECTION 2 **13 questions (70 marks 35 %)**

Answer ALL questions in Section 2 in the spaces provided below.

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1. Write observations for the reactions that occur in each of the following procedures.

In each case describe what you would observe, including any
* colour change
* odour
* precipitate (give the colour)
* Gas evolutions (state the colour or describe as colourless)

If a reaction occurs but the change is not observable, you should state this.

(a) Oxygen gas is bubbled through an acidified solution of iron (II) sulfate.

Observation(s) Colourless odourless gas is bubbled through green solution. Solution turns brown. (2 marks)

(b) Ethene gas is bubbled through bromine water (aqueous solution of bromine).

Observation(s) Colourless gas is bubbled through orange solution and solution decolourises. (2 marks)

2. For each of the following sets of observations:

(i) write a description of any **one** reaction that matches the observations, and

(ii) give an appropriate equation (full or ionic) for **that** reaction.

e.g. A brown solution is added to a colourless solution, producing a brown precipitate.

Reaction *iron (III) nitrate solution is mixed with sodium hydroxide solution.*

Equation $Fe^{3+} + 3\,OH^- \rightarrow Fe(OH)_3$

a) A purple solution is mixed with a colourless solution, producing a ~~colourless~~ light pink solution and a colourless gas

Reaction Acidified permanganate + oxalic acid → CO_2 + hydrogen peroxide → CO_2

Equation $2MnO_4^- + 6H^+ + 5H_2C_2O_4 \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$

$2MnO_4^- + 6H^+ + 5H_2O_2 \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$ (4 marks)

b) A metal strip is placed in a green solution. Silvery-white crystals form on the strip and the green colour fades.

Reaction $Ni^{2+}/Fe^{2+}/Cr^{3+}$ salt + more reactive metal
$Zn/Mg/Al/Mg$ (not Na or Lower)

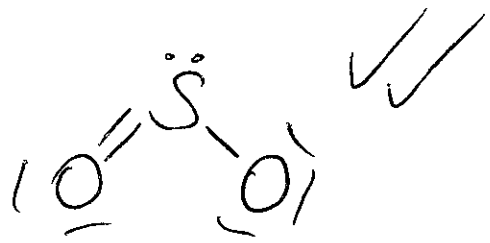
Equation As above

(4 marks)

3. Draw electron-dot diagrams showing the arrangement of all valence electrons in the following chemical species.
Describe the shape of each (eg: linear/bent/etc)

SO_2

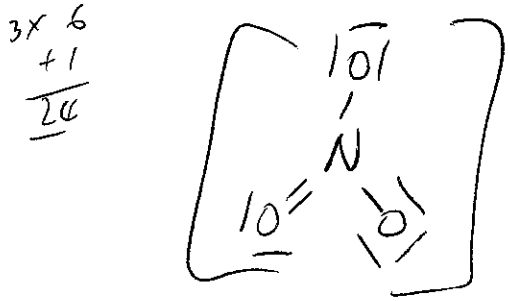
6+12=18



Shape Bent

NO_3^-

N=5
3×6
+1
24



Shape Trigonal Planar

(6 marks)

4. Methane reacts with chlorine to form four different chlorinated compounds.
Write the names and formulae of all the fluorinated methanes that are polar.

CH_3Cl (1-) chloromethane
CH_2Cl_2 (1,1-) dichloromethane
$CHCl_3$ (1,1,1-) trichloromethane

(6 marks)

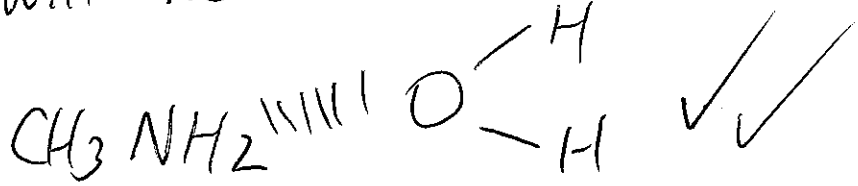
5. The following table shows the solubilities of two amines in water.

Amine	Methyl amine CH_3NH_2	Dodecyl amine $CH_3(CH_2)_{11}NH_2$
Solubility (g/100 mL)	108	0.05

Explain why their solubilities are so different.
Include a labelled diagram.

Predominant force in methylamine is H-bonding ✓✓

Due to length of chain dodecylamine has predominantly dispersion forces ✓✓ and thus will be insoluble in water.



✓✓

(6 marks)

6. Three unlabelled beakers each contain the same volume of 1 mol L^{-1} solution. The three solutions are:

- sodium hydrogensulfate ($NaHSO_4$)
- sulfuric acid (H_2SO_4), and
- phosphoric acid (H_3PO_4).

The student is asked to identify the solutions. He is also given a bottle of sodium hydroxide (NaOH) solution, a choice of indicators and is allowed to use any other item of laboratory glassware. The student was successful.
How did the student correctly identify the acids?
Include equations to support your answer.

Titrate a measured amount against a known volume of NaOH in a burette.

$NaHSO_4$ is monoprotic & requires one volume

$HSO_4^- + OH^- \rightarrow SO_4^{2-} + H_2O$

Sulfuric acid is diprotic requires two volumes

$H_2SO_4 + 2OH^- \rightarrow SO_4^{2-} + 2H_2O$

H_3PO_4 is triprotic & requires 3 volumes

$H_3PO_4 + 3OH^- \rightarrow PO_4^{3-} + 3H_2O$

(7 marks)

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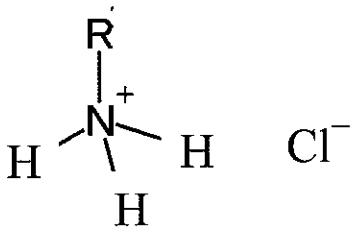
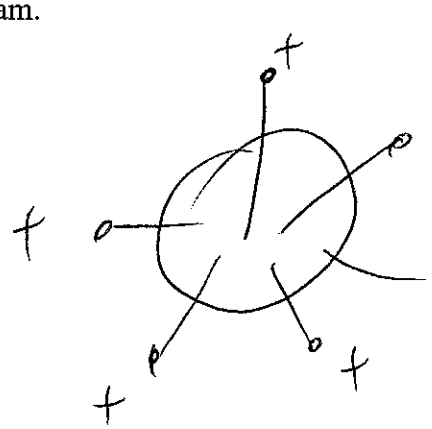
7. Quaternary ammonium salts can be represented by the following structural formula.



If the alkyl group (**R**) is long then the salt acts like a soap or detergent. If it is short the salt has no cleaning properties.
Explain these two differences in properties.
Include a labelled diagram.

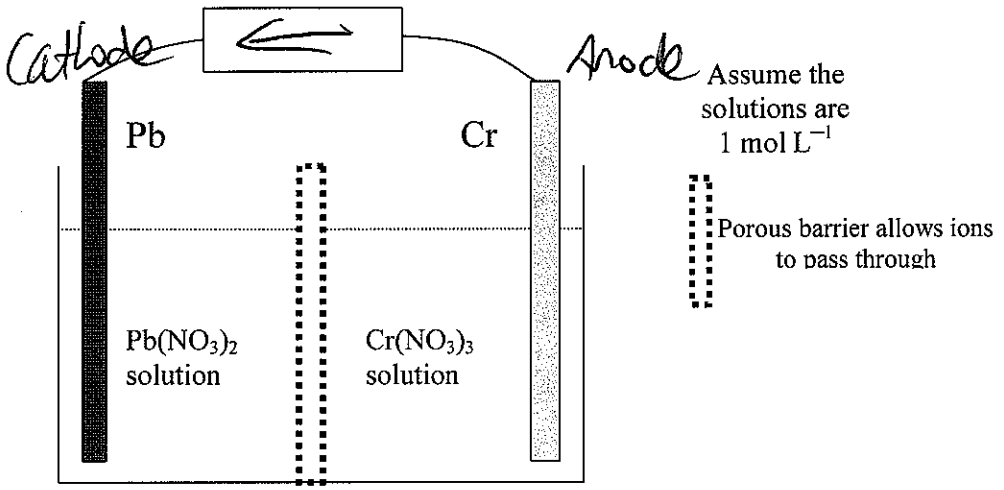


grease (or similar) diagram

The long chain alkyl end contains dispersion forces, and will act to remove non polar substances such as grease and oils. If there is no long carbon chain the grease will not dissolve. The ionic end of the compound will dissolve

(6 marks)

8. An electrochemical cell contains the two half cells separated by a porous membrane, which allows ions to migrate through. Each half cell has a metal electrode placed in a solution of its nitrate.



(a) Write the two half reactions that occur, state whether the half reactions are oxidation or reduction, and list the standard reduction potential.

$(Cr \rightarrow Cr^{3+} + 3e^-) \times 2$ ox E° = +0.74V

$(Pb^{2+} + 2e^- \rightarrow Pb) \times 3$ red E° = −0.13V

E° =

(4 marks)

(b) Write the equation for the net redox equation.

$2Cr + 3Pb^{2+} \rightarrow 2Cr^{3+} + 3Pb$

(2 mark)

(c) What is the emf (electromotive force, or voltage) of the cell?

+0.61V

(1 mark)

(d) Draw an arrow in the top box to show the direction of electron flow in the wire connecting the two electrodes.

see above

(1 mark)

(e) What change (or changes) will be observed in the cell over time?

Lead rod gets thicker, solid forms

Chromium rod becomes thinner.

Chromium solution becomes greene

(3 marks)

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9. The following table gives information about two substances. Use the information to determine whether each substance is acting as an oxidising agent (oxidant), or reducing agent (reductant) and provide a brief explanation to justify your answer.

Substance	Information	Oxidant, or reductant?/ Reason
Concentrated sulfuric acid H_2SO_4	Reacts with copper to produce sulfur dioxide.	Oxidant ✓ sulfur changes from oxidation state +6 to +4 and is reduced. ✓
Hydrogen peroxide H_2O_2	Reacts with chlorine to produce chloride ion. $Cl + e \rightarrow Cl^-$	Reductant ✓ Cl_2 reduces from Cl_2 to Cl^- or oxidation state drops from 0 to −1. ✓

(4 marks)

10. A student pours some silver nitrate solution into a bronze (copper-tin alloy) container.
Is this wise?
Explain why, or why not. Include an equation.

No ✓ silver will reduce into solid silver and will react with the tin and oxidise it to Sn^{2+} ie container will dissolve away ✓✓

could mention +ve emf.

[more to react with tin than copper]

(3 marks)

11. Name, and draw structural diagrams for, the following organic compounds.

Compound	Structural diagram	Name
An isomer of dibromobutane	Matches name ✓✓	1,1 1,2 2,2 2,3 @ 1,3 or 1,4 - dibromobutane ✓
An ester containing 4 carbon atoms	Matches name ✓✓	Methyl propanoate propyl methanoate ethyl ethanoate ✓
The ketone with the least number of carbon atoms	$CH_3\overset{O}{C}CH_3$ ✓✓	Propanone (acetone) ✓

(9 marks)

SECTION 3 **7 questions (80 marks 40 %)**

Extended answers
Answer ALL questions in Section 3 in the spaces provided.

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1. **Treatment of waste by-products in chemical industry** **16 marks**

In a chemical industries complex one production plant produces a waste caustic soda (NaOH) solution, which it stores in a large pond. Another production plant produces waste carbon dioxide. The chemical engineers decide to combine both wastes to produce the environmentally friendly by-product, sodium carbonate, by bubbling the carbon dioxide through the caustic soda solution.

$$2\,NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

The caustic soda pond contains 500 kL and has a hydroxide (OH^-) concentration of 1.00×10^{-2} mol L^{-1}.

(a) What is the pH of the solution?

$[H^+] = \frac{10^{-14}}{0.01} = 1.00 \times 10^{-12}$ mol L^{-1} ✓

$pH = -\log H^+ = -\log 1 \times 10^{-12}$ ✓

$= 12.0$

(2 marks)

(b) What is the mass of sodium hydroxide in the caustic soda pond?

$n(OH^-) = cV$

$= 0.01 \times 500 \times 10^3$

$= 5000$ mol ✓

$m(NaOH) = n \times M$

$= 5000 \times 39.998$

$= 2.00 \times 10^5$ g ✓

(or 200 kg)

$M(NaOH)$

$= 22.99$

16

1.008 ✓

39.998

(3 marks)

(c) What mass of carbon dioxide is needed to completely react with sodium hydroxide?

If you did not answer Part (b) above, use a mass of 100 kg sodium hydroxide

$n(CO_2) = \frac{1}{2} n(NaOH)$

$= \frac{1}{2} \times \frac{5000}{1}$ ✓

$= 2.50 \times 10^3$ mol ✓

$M(CO_2) = n \times M$

$= 2.50 \times 10^3 \times 44.01$ ✓

$= 1.10 \times 10^5$ g

(or 55kg per 100kg NaOH)

$M(CO_2) = 12.01 + 32 = 44.01$ ✓

(4 marks)

(d) The carbon dioxide is first cooled to 10°C and is pumped at a pressure of 200 kPa, delivering 150 L per minute.

How long does it take to complete the reaction?

$PV = nRT$ ✓

$V = \frac{nRT}{P} = \frac{2500 \times 8.35 \times 283.1}{200}$ ✓

$= 2942.4$ L ✓

time $= 2942.4 / 150$ ✓

$= 1.96 \times 10^5$ mins ✓

(5 marks)

(e) The pond solution is still found to be alkaline (pH of about 9).

Assuming all the carbon dioxide has reacted suggest a reason why is it still alkaline.

Sodium carbonate is basic and the carbonate hydrolyses in water to form basic solution ✓

$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$ ✓

(2 marks)

2. **Production of phosphorus from fluoroapatite** **11 marks**

The mineral fluoroapatite [$Ca_{10}(PO_4)_6F_2$] is mixed with sand [SiO_2] and powdered carbon in a high temperature furnace. The phosphorus is produced as a gas [P_2], along with carbon monoxide. The reaction actually produces calcium oxide [CaO], which has a very high melting point. This would make the mixture difficult to control. So, as the calcium oxide is produced it reacts with the sand to form a low melting point slag, calcium silicate [$CaSiO_3$]. This liquid slag is easily separated from the furnace.

The reaction occurring is:

$$Ca_{10}(PO_4)_6F_2\,(s) + 9\,SiO_2\,(s) + 15\,C\,(s) \rightarrow 3\,P_2\,(g) + 15\,CO\,(g) + 9\,CaSiO_3\,(l) + CaF_2\,(s)$$

(a) Is this reaction exothermic, or endothermic? Endothermic ✓

Give a reason for your choice.

Mixture is in a furnace and being heated ✓

(2 marks)

can get reason right if exo/endo is wrong

(b) The main reaction can be represented by the two half reactions:

- phosphate ion producing phosphorus (P_2) and oxide ions (O^{2-}), and
- carbon reacting with oxide ion producing carbon monoxide

Which element, phosphorus or carbon, is being oxidised? Carbon ✓

Justify your answer by referring to oxidation numbers.

Carbon 0 → +2 ✓

Phosphorus +5 to 0

(2 marks)

(c) Some of the oxide ions produced in Part (b) becomes part of the liquid slag by reacting with calcium ions and sand.

Write the equation for the formation of the slag.

$Ca^{2+} + O^{2-} + SiO_2 \rightarrow CaSiO_3$ ✓✓

(2 marks)

(d) In a laboratory trial a 155 g sample of fluoroapatite (molar mass = 1008.62) is heated with excess sand and 25.0 g of carbon.
What mass of phosphorus would be produced?

Limiting Reagent !

$n(C) = \frac{25}{12.01} = 2.08$ mol ✓

$n(Ap) = \frac{155}{1008.62} = 0.1536$ mol ✓

$\therefore \frac{15}{1} = 15$

stoich Actual: $\frac{2.08}{0.1536} = 13.54$

Actual < stoich

∴ C is limiting reagent ✓

$n(P_2) = \frac{3}{15} n(C)$

$= \frac{3}{15} \times 2.08$ ✓

$= 0.4163$ mol

$M(P_2) = n \times M$ $M(P_2) = 2 \times 30.97$

$= 0.4163 \times 2 \times 30.97$ ✓

$= 25.8$ g

If fluoroapatite is L.R. and $n = 28.56$ g then 3 marks.

(5 marks)

3. **Analysing an organic compound** **10 marks**

A certain organic compound is known to contain only carbon, hydrogen and oxygen.
The compound was analysed as follows.

- A 2.149 g sample was burned and the carbon dioxide produced was bubbled through a barium hydroxide solution, producing 11.27 g of barium carbonate ($BaCO_3$).

  $CO_2 + Ba(OH)_2 \rightarrow BaCO_3 + H_2O$
- The mass of water produced by burning the sample was 0.7721 g
- The compound was found to have a molecular weight of 150.1

a) What is the empirical formula of the compound? (7 marks)

[*You may do this by finding the masses of carbon, hydrogen and oxygen in the sample*]

b) What is the molecular formula of the compound? (2 marks)

c) The compound is also known to be a carboxylic acid; that is, containing one COOH group.
Write the molecular formula in the form of $C_XH_Y O_Z$ COOH (giving values for X, Y and Z).
(1 mark)

$n(H) = 2n(H_2O) = 2 \times \frac{0.7721}{18.016} = 0.08571$

$m(H) = n \times M = 0.08571 \times 1.008 = 0.08639\ g$ ✓

$n(BaCO_3) = \frac{m}{M} = \frac{11.27}{197.31}$

$= 0.05711\ mol$

Ba = 137.3
C = 12.01
3×O = 48
197.31 ✓

$n(C) = n(CO_2) = n(BaCO_3)$

$= 0.05711\ mol$ ✓

$m(C) = n \times M = 0.05711 \times 12.01$

$= 0.6859\ g$

$\therefore m(O) = 2.149 - 0.6859 - 0.08639$

$= 1.3766$

$n(O) = 0.08604\ mol$ ✓

C	H	O
$\frac{0.05711}{0.05711}$	$\frac{0.08573}{0.05711}$	$\frac{0.08604}{0.05711}$
1	1.5	1.5 ✓

$\therefore$ Ef is $C_2H_3O_3$. ✓

(b) $M(Ef) = 2\times12.01 + 3\times1.008 + 3\times16 = 75.04$ ✓

$M(Mf) = 2M(Ef)$ ✓

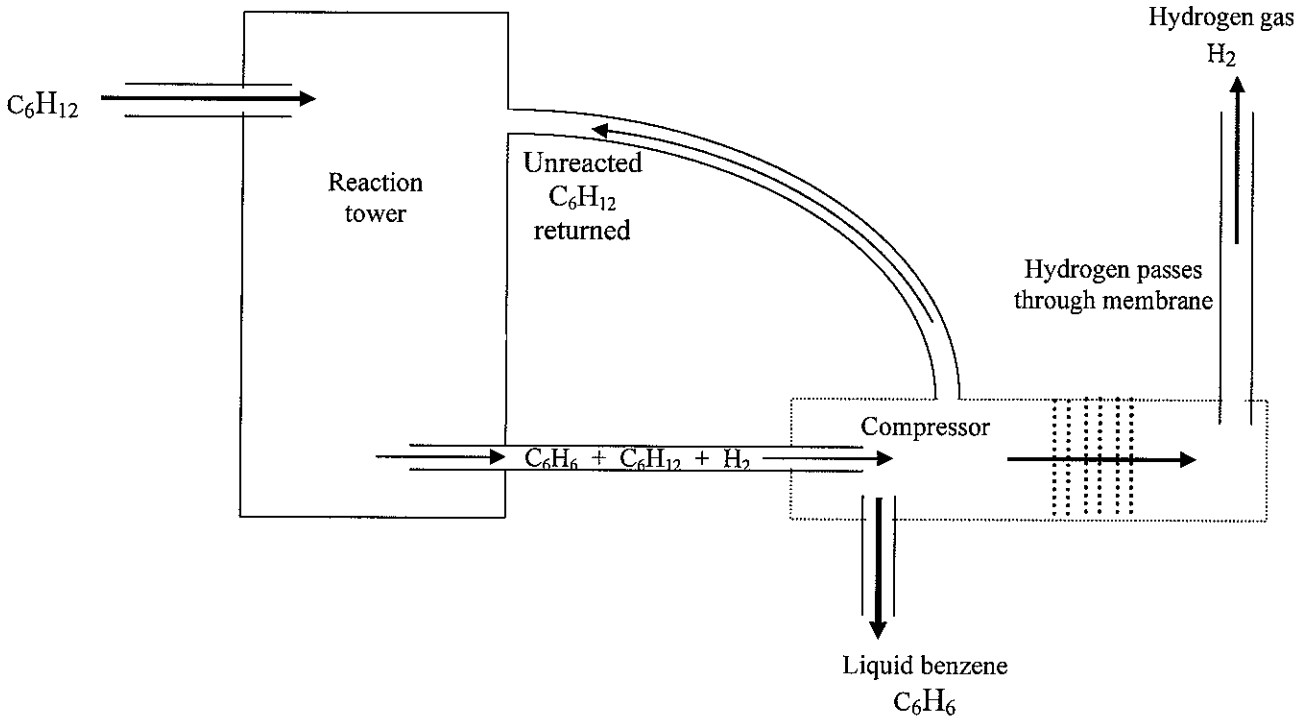
$\therefore$ Mf is $C_4H_6O_6$. ✓

(c) $C_3H_5O_4COOH$ ✓

4. **Production of benzene** **11 marks**

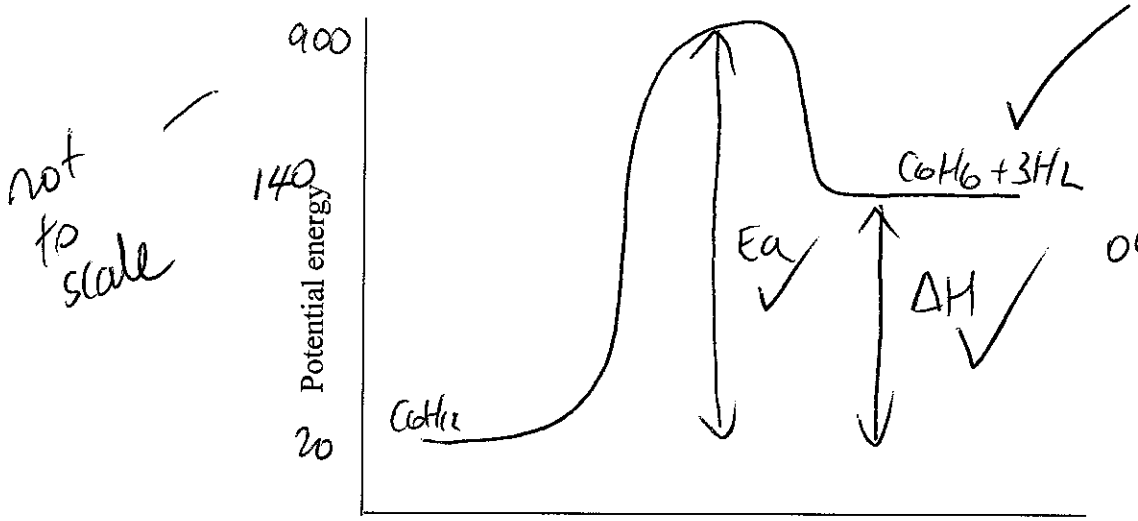
Benzene (C_6H_6) can be produced by the dehydrogenation of cyclohexane (C_6H_{12}) gas. The reaction has a high activation energy (880 kJ mol^{-1}), is also endothermic and reversible. The cyclohexane (C_6H_{12}) passes through a special reaction tower where hydrogen is chemically removed. The benzene/cyclohexane/hydrogen mixture then passes through a compressor, where the benzene is liquefied. A special membrane in the compressor allows the small hydrogen molecules to pass through, and out. The unreacted cyclohexane (C_6H_{12}) gas is then returned to the reaction tower.

$$C_6H_{12}\,(g) + 120\ kJ \rightleftharpoons C_6H_6\,(g) + 3\,H_2\,(g)$$



a) Draw a labelled energy profile diagram for the reaction. Include

- ~~Activation energy~~
- ~~H~~
- ~~Reactants and products~~



not to scale

no mark paid if number not evident

or Ea ΔH labelled with numbers

(3 marks)

SEE NEXT PAGE

b) Write an equilibrium constant expression for the reaction.

$$K = \frac{[H_2]^3 \times [C_6H_6]}{[C_6H_{12}]}$$ ✓✓

(2 marks)

c) For a mixture of all three gases at equilibrium in a sealed container, what conditions will produce the maximum equilibrium yield of benzene?

Lower pressure ✓

Very high temperature ✓

(2 marks)

d) Suggest conditions that would be used for the commercial production of benzene using this process. Explain why you chose these conditions. Include safety and economic considerations.

State Le Chateliers Principle ✓ (if merit)

Very high temperature favours high yield and fast rate, but is expensive ✓
∴ compromise is high to very high temperature.

High pressure favours rate but favours reverse reaction, and is expensive/dangerous thus compromise is moderate pressure ✓

catalyst increases rate of attainment of equilibrium ✓

(4 marks)

5. **Determining concentration of cerium (II) sulfate solution by titration** **10 marks**

Cerium (II) ion can be converted to cerium (III) ion by hydrogen peroxide.
$H_2O_2 + 2\,H^+ + 2\,Ce^{2+} \rightarrow 2\,H_2O + 2\,Ce^{3+}$ (cerium is element 58)

A solution of cerium (II) sulfate was analysed by the following steps:

I. 50.00 mL of the solution was diluted to 500.0 mL in a volumetric flask

II. 20.00 mL of this diluted solution was pipetted into a conical flask

III. About 20 mL of dilute sulfuric acid was added to the flask

IV. Standardised hydrogen peroxide solution of concentration 0.05145 mol L^{-1} was delivered from a burette

V. 35.45 mL of the hydrogen peroxide was required for complete reaction

(a) $(Ce^{2+} \rightarrow Ce^{3+} + e^-) \times 2$
$H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$ final eqn above

What was the concentration in moles per litre (mol L^{-1}) and in grams per litre (g L^{-1}) of the original undiluted cerium sulfate solution?

(b) $n(H_2O_2) = cV$
$= 0.05145 \times 0.03545$
$= 1.82 \times 10^{-3}$ mol

$n(Ce^{2+}) = 2n(H_2O_2)$
$= 2 \times 1.82 \times 10^{-3}$
$= 3.65 \times 10^{-3}$ mol

$n(Ce^{2+})_{\text{in 500mL}} = \frac{500}{20} \times 3.65 \times 10^{-3}$
$= 9.12 \times 10^{-2}$ mol

$\therefore c(Ce^{2+}) = \frac{n}{V} = \frac{9.12 \times 10^{-2}}{0.05} = 1.82$ mol L^{-1}

$\therefore \rho = 1.82\ldots \times 236.17$
$= 431$ g L^{-1}

$M(CeSO_4) = 140.1 + 32.07 + 64 = 236.17$

6. **Manufacture of Phosphoric Acid** **10 marks**

Pure phosphoric acid is a white solid with a melting point of 42°C. Thermal process phosphoric acid is produced from gaseous phosphorus by the electric furnace method shown below:

NB Equations are unbalanced

Step 1: $P_4(g) + 5\ O_2(g) \rightarrow P_4O_{10}(s)$

Step 2: $P_4O_{10}(s) + 6\ H_2O(l) \rightarrow 4\ H_3PO_4(aq)$

Step 3: $(4\ H_3PO_4(aq) \rightarrow 4\ H_3PO_4(s)) \times 4$

The phosphoric acid produced is quite pure and is suitable for most industrial processes, although small amounts of arsenic (present as H_3AsO_4) must be removed if the acid is destined for food or pharmaceutical use.

The following table represents the weekly output of phosphoric acid for a one month period.

Week Number	Tonnage output of Phosphoric acid
1	1.347
2	1.129
3	1.093
4	1.226

(a) Calculate the average weekly tonnage output of phosphoric acid for the four week period. (1 mark)

$$\text{ave} = \frac{1.347 + 1.129 + 1.093 + 1.226}{4}$$

$$= 1.199 \text{ tonnes}$$ ✓

(b) Balance the equations above and use the equations to determine the number of moles of gaseous phosphorus needed to produce 1 mole of solid phosphoric acid. (2 marks)

1 for balancing two equations ✓

$$n(P_4) = \frac{1}{4} n(H_3PO_4)$$

$$= 0.250 \text{ moles}$$ ✓

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(c) Assume the process is 96% efficient, calculate the average weekly usage of phosphorus gas for the four week period shown in the table. (4 marks)

does not specify moles or mass

$n(H_3PO_4) = \frac{m}{M}$

$= \frac{1.199..\times10^6}{97.994}$

$= 1.22\times10^4$ mol ✓

$M(H_3PO_4) = 3\times1.008 + 30.97 + 64 = 97.994$ ✓

$n(P_4) = 0.25\times n(H_3PO_4)$

$= 0.25\times1.22\times10^4$

$= 3.06\times10^3$ mol ✓

But 98% efficient ∴ $n(P_4) = \frac{100}{96}\times3.06\times10^3$ ✓

$= 3.19\times10^3$ mol ✓ ✓

∴ $M(P_4) = 3.19\times10^3\times4\times30.97 = 3.95\times10^5$ g

(d) A chemist wants to determine the level of arsenic (H_3AsO_4) in the acid supply. The analyst does several tests on 100 gram samples of the acid during the fourth week and finds the average sample contains 0.800 mg of arsenic (H_3AsO_4) per 100 grams of phosphoric acid. Determine the total mass and moles of H_3AsO_4 that would need to be removed from the phosphoric acid in order for it to be sold to the pharmaceutical or food industries. (3 marks)

$m(H_3PO_4) = 1.226\times1000$

$= 1226$ kg

$m(H_3AsO_4) = \frac{0.8}{1000}\times1226\times10$

$= 9.89$ ✓

$M(H_3AsO_4) = 3\times1.008 + 74.92 + 64 = 141.944$ ✓

$n(H_3AsO_4) = \frac{9.8}{141.944}$

$= 6.91\times10^{-2}$ mol ✓

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7. A student is asked to identify four organic liquids, contained in four separate flasks. **12 marks**

- Octene
- Hexan-3-ol (3-hexanol)
- Hexan-3-one (3-hexanone)
- Butanoic acid

(a) Using your knowledge of organic chemistry, compare the structures of each and discuss the predominant type of intermolecular force present in each of the liquids.
(b) The student has access to any chemicals and glassware required. Describe the chemical tests that should be carried out and the observations made, that enable the liquids to be identified. Include balanced equations to justify the choice of tests.

Write your response in 1-2 pages.

oct-1-ene ✓

(a) • $CH_2CHCH_2CH_2CH_2CH_2CH_2CH_3$

Alkene, double bond between 1st and 2nd carbons ✓

Predominant force is dispersion force. ✓

• Hexan-3-ol $CH_3CH_2CHCH_2CH_2CH_3$ (OH)

Secondary alcohol, -OH group is on 3rd carbon ✓

Predominant force is H-bonding ✓

• Hexan-3-one $CH_3CH_2C(=O)CH_2CH_2CH_3$ ✓

Ketone, carbonyl group on 3rd carbon ✓

Predominant force is dipole to dipole interaction. ✓

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• Butanoic acid $CH_3CH_2CH_2COOH$ ✓

Carboxylic acid predominant force is H-bonding ✓

(b) • octene, react with bromine water

$CH_2CHCH_2CH_2CH_2CH_2CH_3 + Br_2 \rightarrow CH_2CHCH_2CH_2CH_2CH_2CH_3$
Br Br ✓

Bromine water decolourised ✓

• Hexan-3-ol, react with acidified dichromate ✓ or permanganate solution

$(MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O) \times 2$
$(C_6H_{14}O \rightarrow C_6H_{12}O + 2H^+ + 2e^-) \times 5$ ✓
$2MnO_4^- + 6H^+ + 5C_6H_{14}O \rightarrow 5C_6H_{12}O + 2Mn^{2+} + 8H_2O$

Solution turns from purple to pale pink

• Butanoic acid, react with sodium carbonate. Solution will fizz a colourless odourless gas. ✓

$2CH_3CH_2CH_2COOH + Na_2CO_3 \rightarrow 2NaBu + CO_2 + H_2O$ ✓

or appropriate

• Remaining solution is hexan-3-one

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