



General Comments

A total of 577 students were assessed externally for CH856 Chemistry 12C; compared with 572 in 1998.

The examination was generally regarded as a little easier than the previous year's and the overall performance by most candidates was very pleasing with approximately a quarter of all students gaining OA award.

Question 1 — Criterion 10

- (a) (i) Generally well done as far as method was concerned although an alarming number of students (nearly 50%) failed to deduce that there were two K^+ ions in K_2SO_4 . Part marks were given on merit for a correct calculation even when this error was made. (The correct answer was 34.8 g)
- (ii) Most students lost one mark for either:
- failing to convert mL to L
 - using the mass of K_2SO_4 instead of K^+ .
 - incorrectly converting g to mg (often dividing by 1000 instead of multiplying)
(The correct answer was 0.782 mg)
- (b) (i) Generally well done although the most common errors were:
- using the wrong molar mass for $BaSO_4$ despite the value being given.
 - using 10.0 mL in the calculation for concentration, ie. not converting to L.
(The answer was $0.0292 \text{ mol L}^{-1}$)
- (ii) Most students used a correct method for this question. Students who used an incorrectly calculated value from part (i) were still accorded full marks provided their method was correct. (The correct answer was 1.46 mL)
- (c) (i) and (ii) Although generally well done, these pH calculations caused severe problems for some students who appeared unable to use a logarithmic function. A significant minority of students in part (ii) also made the following errors:
- added 250 mL to 500 mL and used 750 mL as the total volume.
 - claiming that if the [acid] was halved, the pH would double from 2 to 4.
 - failed to convert mL to L in the calculation.
(answers: (i) pH = 1.00 (ii) pH = 2.30)
- (d) This was more difficult for students than earlier parts. There was a general lack of understanding that $\text{pH} + \text{pOH} = 14.0$ at 25°C ; ie. $[\text{H}^+(\text{aq})][\text{OH}^-(\text{aq})] = 1.00 \times 10^{-14}$

Most students had little idea of what to do in this part. (The answer was 0.100 mol L^{-1})

- (e) This was a very long question for 4 marks and many students failed to complete the question or omitted it altogether. The main errors were:
- handling the $[\text{H}^+(\text{aq})]$ from the H_2SO_4 .
 - calculating the amount of $\text{OH}^-(\text{aq})$ in excess.
 - understanding that there are still some H^+ even when OH^- is in excess.
 - asserting that as $\text{OH}^-(\text{aq})$ was in excess then the $[\text{H}^+(\text{aq})]$ would be zero.
 - calculation of $[\text{OH}^-(\text{aq})]$ from the increased volume of solution.

The markers decided to award one bonus mark to every student who got the question correct in every detail of method and answer. (The upper limit of 20 marks for the whole question was still observed). (The answer was $7.50 \times 10^{-14} \text{ mol L}^{-1}$)

Question 2 — Criterion 10

Generally, this question was well done with good setting out and appropriately structured answers showing formulae, symbols and units. The biggest irregularity occurred with the use of significant figures. Students should remember to give answers to the same number of figures as used in the question when appropriate.

- (a) The units for the kelvin scale should be K not °K.
- (b) This question gave every quantity to 4 sig. figs. and yet many gave their answers to only 2 significant figures. These errors were penalised by deducting marks for Criterion 2. Quite a number of students claimed that their answer of 0.031 mol was to 4 sig. figs when in fact it is only 2. The limiting number of 3 sig. figs. was with the gas constant (8.31 or 0.0821).

Some students used $R = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}$ but did not convert the pressure to atmospheres. The text book uses $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$ almost exclusively hence it would be more consistent and generally easier if students were encouraged to follow the text.

- (c) (i) This was reasonably well answered but the most common problem was converting from the volume of oxygen required to the volume of air. Once again, sig. figs. were a common problem.

Note that answers like 'volume = 125802.8 L (to 7 s.f.)' is still inappropriate even though the number of significant figures is stated.

- (ii) Many unexpected answers appeared for this part and indicated that students were unfamiliar with the practicalities of gas cylinder usage. Some part marks were given for the less likely explanations such as:
- LPG may not be pure propane or incomplete combustion may occur.
 - some LPG may have been lost before/during combustion.

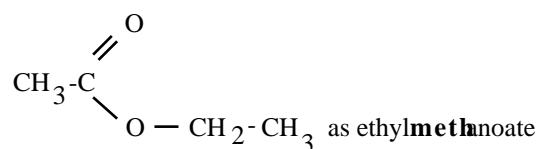
Some of the incorrect answers included references to temperature changes, E_a effects, reaction rates and chemical equilibrium. Some said that there would be liquid propane remaining.

Many students forgot to comment on the *significance* of the change in volume of air required.

Question 3 — Criterion 9

This question was exclusively organic chemistry and was generally very done although the following is a list of commonly made errors.

- (a) (i) & (iv) plus (b)(iv) - not numbering the longest carbon chain from the end of the molecule with the functional group.
- (a) (iv) Missing the H atom from the carbon in the carboxyl group.
- (b) (i) Writing butanol instead of butan-1-ol.
- (ii) Confusion between the 'eth' and 'meth' prefixes when one carbon of the 'eth' is part of the functional group, hence naming

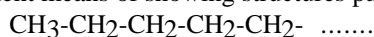


- (iii) Not recognising the longest carbon chain.
- (c) (i) Not recognising that an *empirical* formula and not a molecular formula was given and hence being forced to claim that aldehydes were acidic.

This question required that students showed *how* their compound's structure fitted the given properties. Explanations were often omitted.
- (ii) Not recognising that Mg being divalent would react with the acid in a mole ratio of 1:2
- (d) (i) Not realising that the compound was non-acidic.
- (ii) In this part, isomers of esters were expected, but as the question did not make that totally clear, all reasonable acidic and non-acidic isomers of C₄H₈O₂ were accepted.
- (iii) Not knowing that a concentrated mineral acid (eg. H₂SO₄) was required as a catalyst.

Some general points:

1. Is it possible that some schools are not teaching systematic (IUPAC) nomenclature for all functional groups? References to 'acetaldehyde' by a number of students suggested this. 'Acetic' acid and 'ethyl acetate' also appeared occasionally.
2. When writing structural formulae, quite a few students drew the C-H bonds in but did not show the H atoms. Although marks were not deducted, it is suggested that teachers discourage this practice. Condensed structural formulae are a convenient means of showing structures particularly in long chains; eg.



Question 4 — Criterion 9

- (a) A significant number of students believed that a gas diffuses through air (of the same temperature) because of a higher average E_K and hence a higher average molecular speed than the surrounding air molecules. Higher pressure and also lower density of the H_2S gas were also fairly commonly given as reasons for its diffusion.
- (b) A surprisingly wide variety of unbalanced equations appeared in answers. The names 'sulfurous acid' and 'sulfuric acid' were often interchanged.
- (c) (i) Periods 2 and 4 were frequently misinterpreted as being Periods 3 and 5 respectively. Some students used Alkaline Earth (Group II) elements instead of Alkali Metals (Group I). The examiner generously accepted this error.
- (ii) It was worrying to see formulae such as K_2F and to a lesser extent FK .
- (iii) Reference was commonly made to the lower first ionization energy being due to the element's position in the Periodic Table or to its electronegativity rather than considering the reasons why the outermost electrons of different elements are attracted differently by their nuclei.
- (iv) This part of the question proved to be the most difficult for many students. The fact that metallic *oxides* are (generally) basic needed to be recognised as well as the need to consider more than one atom of the element Y in the formula;
- ie. Y_2Z is probably K_2O . Just using the formula Y_1Z led students to come up with over twenty different possibilities for Z.

Few students wrote the balanced equation showing the formation of aqueous hydroxyl ions.

- (d) A surprising number of students referred to Fl^{1-} and even Fe^{1-} in their answers. A complete answer required reference to relative numbers of protons and electrons in determining the radii. It was insufficient to simply refer to a trend across a period without some reasons.
- (e) Confusion was noted between the actual electronic energy levels and the energy required to remove an electron from an atom.

Far too many answers involved suggestions of the 'wishes' and 'feelings' of electrons and atoms!

Question 5 — Criterion 8

- (a) (i) The calculations were well done in general but many students got the answer with a + H (endothermic) because they incorrectly used bond energies in the equation:

$$H = H(\text{PRODUCTS}) - H(\text{REACTANTS})$$

Many students made calculation mistakes because of the poor setting out of their answers. A suggested method is to find the energy required to break all bonds in the reactants (+H1 kJ) and then find the energy released when all the new bonds form in the products (-H2 kJ).

H is the numerical sum of the positive H1 term and the negative H2 term.

- (ii) This was very poorly done. Students did not display that they understood the meaning of the term 'enthalpy' as opposed to ΔH (enthalpy change). To obtain full marks, students were required to state that the enthalpy (heat content) of the reactants was considerably higher than the heat content of the products. In addition, it was expected that students would state that the energy needed to break the bonds in the reactants was much less than the energy released when the new bonds formed in the products. An Ep diagram helped gain high marks.
- (iii) The quality of diagrams was frequently poor due to them being too small, unlabelled, roughly drawn and lacking information. For full marks, students needed to state that this reaction has a relatively high E_a barrier and that the vast majority of collisions between ethanol and oxygen molecules were insufficiently energetic to cross this E_a barrier and thus the reaction is non-spontaneous. This argument needed to be backed up with an appropriate Ep diagram.
- (b) (i) The majority of students identified $\text{Cu}_{(s)}$ as a catalyst.
- (ii) The quality of diagrams was poor as in part (a)(iii). To obtain full marks, students were required to state that the catalyst provided a different reaction mechanism (pathway) with a lowered the E_a barrier but that the value of ΔH was not affected. This argument needed to be backed up with an appropriate Ep diagram.
- (c) Very well done although quite a few students had trouble working with the MJ and kJ units.

Students must be encouraged to consider whether their answers are 'realistic'. In this question answers ranged from a few milligrams through to 10^{20} kg!

Question 6 — Criterion 8

This question was not well answered by the majority of students with the average mark being only 12 out of 20. The marks obtained were polarised, indicating that students either had a very good knowledge of equilibrium or, alternately, they were weak in this area.

- (a) (i) It was acceptable to write a ' K_C ' format answer; ie. to include the solid term on the denominator. The most common errors were to omit the squared term for the chloride ion concentration and to omit the charges on the ions. Omission of the 'aqueous' and 'solid' state terms was penalised in Criterion 2.
- (ii) Many students gave a correct answer by merely transcribing details from their textbook. Some confused K_C with ΔH and said that the equilibrium constant gave information that the reaction was endothermic.
- (iii) This was not answered at all well with many strange answers including:
- the fact that solids are '100% pure which is 1.00'
 - solids don't have concentrations
 - 1.00 is assigned for convenience only.

Bonus marks were awarded to students who not only stated that the concentration of a solid was a constant (T const) but who showed that the product:

$K_C \times [\text{solid}] = \text{another constant}$, although reference to K_{SP} was not expected.

- (iv) Some used information directly from their texts to state the correct answer but gave no explanation as requested. Others said that the K_C value and the $[\text{Pb}^{2+}(\text{aq})]$ both increased *because* of Le Chatelier's Principle.
- (b) (i) The relationship $[\text{H}_3\text{O}^+(\text{aq})] = 10^{-\text{pH}}$ was not well understood and calculation errors were frequent. A common mistake was $[\text{H}_3\text{O}^+(\text{aq})] = 10^{+1.9} = 78 \text{ mol L}^{-1}$
- (ii) The degree of dissociation (or ionization) was often overlooked and answers often suggested that the amount *dissolved* was the determining factor.

Others stated that a pH of 1.9 gives a more acidic solution than a pH of zero. A common misconception was that a pH = 0 means that the solution has no acidity at all! Although there is an indirect connection, answers saying that 'the Cl and COOH groups were the cause' offered too little to gain more than 1/2 mark. A surprising number of students said that the methanoic acid dissociated to release hydroxyl ions.

- (c) This question was deceptively simple and most who attempted it did reasonably well.
- (i) Well done except that some gave the reciprocal expression.
- (ii) Most substituted into K correctly but many then had trouble correctly rearranging the terms. Calculation errors involving powers of 10 were common.
- (iii) A frequent error was to obtain the relationship that $[\text{HBtB}] = 100 \times [\text{BtB}^-]$ and then state that the $[\text{BtB}^-]$ was 100 times larger than the $[\text{HBtB}]$. Some students were hesitant about the colour and often opted for the solution being 'greeny yellow' or even 'yellowy blue'.
- (iv) This part was not well done with calculation errors again being the principal cause for concern.

Question 7 — Criterion 7

As it turned out, this question was regarded as being relatively easy by most students and the majority presented a pleasing quality of work involving answers showing a generally good understanding of electrochemistry.

- (a) (i) Most students managed to answer this part without any difficulties.
- (ii) A large number of students appeared to have no knowledge of oxidation states.
- (iii) Most students answered this part correctly although quite a few insisted in using O_2 , O or even O^{2-} instead of H_2O to balance oxygen in the half-equations.
- (iv) This question was easy for those who answered part (iii) correctly.

- (b) This part of the question was well constructed, enabling students to exhibit their knowledge in this criterion.
- (i) Almost all students obtained full marks.
 - (ii) The majority gained 1 or 2 marks but some had no idea of how to use E° data.
 - (iii) Most students scored well on this question. The most common error was to assume that $n(e^-) = n(\text{Zn})$. The conversion of 3.03×10^8 seconds to 9.59 years was beyond many. The penalty for an incorrect conversion was only 1/2 mark.
 - (iv) Failure to denote the correct chemical species was a common error in this question. Failure to write out the 1/2 equations often resulted in students stating that the EMF of the cell $\text{Ag}/\text{Ag}^+//\text{O}_2/\text{OH}^-/\text{Pt}$ was +0.40 V rather than -0.40 V. Thus, many said that silver would be a suitable alternative to zinc.

The best answers to this part referred to the fact that silver being a weaker reducing agent than OH^- means that Ag will not react spontaneously with $\text{O}_2(\text{aq})$.

Question 8 — Criterion 7

This question was generally well done but because the expected answers were of a descriptive nature, this meant that gaining full marks was unlikely.

- (a)
 - (i) The answer expected reference to the fact that tin is a noble coating and provides an unreactive barrier between the iron and O_2 /water. Many thought that tin was a sacrificial coating.
 - (ii) A significant number of students didn't explain why the rate of corrosion was increased. To gain full marks for this section required the appropriate half-equations. A common error was that Sn^{2+} was reduced at the cathode.
- (b) Two approaches were acceptable here. Either the Zn coating reacting with 'food acids' or the Zn corroding if the coating was damaged. Although chemical equation(s) were asked for, they were seldom given.
- (c)
 - (i) The flow of ions was often omitted, particularly the cations.
 - (ii) A bonus mark was awarded to students who corrected the mistake in the half-equation. A number of students used $\text{Ag}^+(\text{s})$ as the reactant rather than Ag_2S .
 - (iii) Many strange gases were invented to answer this part; eg. hydroxide gas, S^{2-} -gas, SO_2 , ... Many opted for oxygen gas to be formed at the *cathode* despite the fact that the information showed O_2 being formed at the anode. H_2S gas was also a popular alternative but any such release would most likely occur around the anode due to the increased acidity.
 - (iv) Students generally did not suggest appropriate pollutants or their origins. In many answers, pollution was said to be due to motor vehicles only. An alarming number of students had sulfur gas or S^{2-} gas as the cause. Very few chemical equations were presented as justification for answers.

- (v) As the chemistry of rhodium was not known to students, the examiners were prepared to accept any reasonable attempt at an answer whether it be based on Rh being a noble coating or a sacrificial type. Rhodium, in fact has properties somewhat like platinum.

Criterion 2

For comments on the assessment and data analysis for this criterion and for statistical data relating to individual exam questions and the overall paper, see the summary in the attachment (following).

Statistical Summary

Award Summary

Outstanding Achievement (OA)	176
High Achievement (HA)	183
Satisfactory Achievement (SA)	172
Reassessed into neighbour	57
Total	588

Gender Breakdown

Males	296
Females	292

Summary of external ratings

	A	B	C	D
Criterion 2	193	200	160	33
Criterion 7	156	211	135	84
Criterion 8	164	168	147	107
Criterion 9	167	200	137	82
Criterion 10	197	184	130	74

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CHEMISTRY "12C" EXAM (TCE)

NOVEMBER 1999

ANSWER SUMMARY

21. (a) (i) $n(K_2SO_4) = \text{molarity} \times L$

But $K_2SO_4(s) \rightarrow 2K^+(aq) + SO_4^{2-}(aq)$

$\therefore [K^+] = 0.400 \text{ mol L}^{-1}$ means

$[K_2SO_4] = 0.200 \text{ mol L}^{-1}$

$\therefore \text{mass } K_2SO_4 = (0.200 \times 100 \times 174) \text{ g}$

$= 34.8 \text{ g}$

(ii) $n(K^+) = \text{molarity} \times L$

$= (0.400 \times 0.0500 \times 10^{-3})$

$= 2.00 \times 10^{-5} \text{ mole}$

$\therefore \text{mass of } K^+ = \{ \text{mole} \times A_r(K) \} \text{ g}$

$= (2.00 \times 10^{-5} \times 39.1) \text{ g}$

$= 7.82 \times 10^{-4} \text{ g}$

(i) $n(BaSO_4) = \frac{\text{mass}}{M_r} = \left(\frac{0.0680}{233} \right)$

$= 2.92 \times 10^{-4} \text{ mol}$

$\therefore n(Ba^{2+}) = 2.92 \times 10^{-4} \text{ mol}$

$[Ba^{2+}] = \frac{\text{mole}}{L} = \frac{2.92 \times 10^{-4}}{10.00 \times 10^{-3}}$

$[Ba^{2+}] = 0.0292 \text{ mol L}^{-1}$

(ii) $n(Ba^{2+}) = 2.92 \times 10^{-4} \text{ mol}$

$\therefore n(K_2SO_4) \text{ needed} = 2.92 \times 10^{-4} \text{ mol}$

$\therefore \text{litres of sol}^n \text{ needed is}$

$L = \frac{\text{moles}}{\text{molarity}} = \frac{2.92 \times 10^{-4}}{0.200}$

$= 0.00146 \text{ L}$

$\therefore \text{Volume needed} = 1.46 \text{ mL}$

(c) (i)

$[HCl] = \frac{\text{mole}}{L} = \frac{0.01000}{0.1000}$

$= 0.100 \text{ mol L}^{-1}$

$\therefore 100\% \text{ dissociate} \rightarrow [H^+] = 0.100 \text{ mol L}^{-1}$

$\therefore \text{pH} = -\log(0.100)$

$= +1.00$

(ii) now $[HNO_3] = 0.100 \text{ mol L}^{-1} \times \frac{250}{500}$

$= (10^{-2} \times \frac{250}{500})$

$= 5.00 \times 10^{-3}$

$\therefore \text{pH} = -\log(5.00 \times 10^{-3})$

$= 2.30$

(d) $\text{pH} = 13.0: [H^+] = 1.00 \times 10^{-13}$

$\therefore [OH^-] = \frac{1.00 \times 10^{-14}}{1.00 \times 10^{-13}} * (K_w = 10^{-14})$

$= 0.100 \text{ mol L}^{-1}$

(NB: $[H^+][OH^-] = K_w = 1.00 \times 10^{-14}$ @ 25°C)

(d) $H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$

$n(H_2SO_4) \text{ added} = \text{molarity} \times L$

$= 0.400 \times 10.0 \times 10^{-3}$

$= 4.00 \times 10^{-3} \text{ mol}$

$\therefore n(H^+) \text{ added} = 8.00 \times 10^{-3} \text{ mol}$ *

$n(KOH) \text{ present} = \text{molarity} \times L$

$= 0.600 \times 20.0 \times 10^{-3}$

$= 12.0 \times 10^{-3} \text{ mol}$ *

Comparing * and *, there are

$4.00 \times 10^{-3} \text{ mol}$ of OH^- unreacted

in a total of 30.0 mL

$\therefore [OH^-] = \frac{\text{mole}}{L} = \frac{4.00 \times 10^{-3}}{30.0 \times 10^{-3}} = 0.133 \text{ mol L}^{-1}$

$\therefore [H^+] = \frac{1.00 \times 10^{-14}}{0.133} = 7.50 \times 10^{-14} \text{ mol L}^{-1}$

QUESTION 2.

(a) $S.L.C. = 25^\circ C @ 101.3 \text{ kPa}$

$= 298 \text{ K} @ 101.3 \text{ kPa}$

(b) (i)

$V_1 = 750.0 \text{ mL}$

$T_1 = 298 \text{ K}$

$P_1 = 101.3 \text{ kPa}$

$V_2 = ? \text{ mL}$

$T_2 = 223.5 \text{ K}$

$P_2 = 303.9 \text{ kPa}$

$\therefore \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow V_2 = \frac{P_1 V_1 T_2}{P_2 T_1}$

$\therefore V_2 = \left(\frac{750.0 \times 223.5 \times 101.3}{303.9 \times 298} \right) \text{ mL}$

$= 187.5 \text{ mL}$

$\therefore \text{Final volume} = 187.5 \text{ mL}$

(ii) $n(\text{gas}) = \frac{PV}{RT} = \left(\frac{101.3 \times 0.7500}{8.31 \times 298} \right)$

$n = 0.0307 \text{ mol}$

$\therefore \text{no. of mol of gas} = 3.07 \times 10^{-2}$

(c) $n(C_3H_8) = \frac{\text{mass}}{M_r} = \frac{10.0 \times 10^{-3}}{44.0}$

$= 2.27 \text{ mol}$

$\therefore n(O_2) \text{ needed} = 2.27 \times \frac{5}{1} = 11.36 \text{ mol}$

$\therefore \text{Vol of } O_2 \text{ needed}$

$V = \frac{nRT}{P} = \left(\frac{11.36 \times 8.31 \times 298}{102} \right)$

$\text{Vol. of } O_2 = 2.63 \times 10^4 \text{ L}$

$\therefore \text{Vol of air} = \left(2.63 \times 10^4 \times \frac{100}{20.9} \right) \text{ L}$

$= 1.26 \times 10^5 \text{ L}$

(ii) The C_3H_8 will only escape

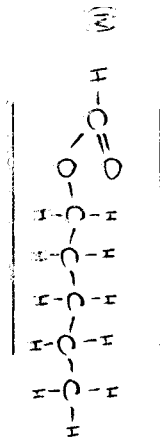
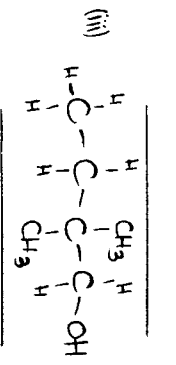
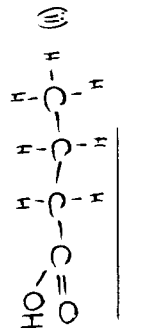
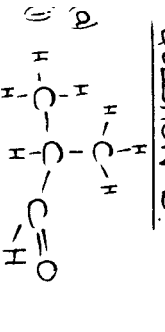
from the cylinder so long as the pressure inside is greater than the external (atm) air pressure.

Thus, when the internal pressure gets down to 102 kPa, the C_3H_8 will not escape and so the final cylinder volume of C_3H_8 is not burnt.

This unburnt portion represent a tiny fraction of the original 10.0 kg which was mostly liquefied C_3H_8 .

$\therefore \text{Vol of air required will still be } \approx 1.26 \times 10^5 \text{ L}$

QUESTION 3.



(b) (i) butan-1-ol

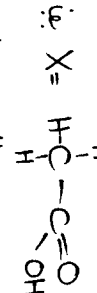
(ii) ethylpropanoate

* (iii) 2-methylpropanoic acid

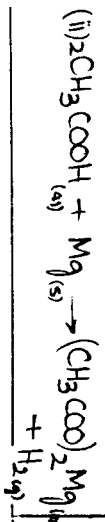
(iv) 2,2,2-trichloroethanal

(The 2,2,2- is unnecessary)
* methylpropanoic acid is sufficient!

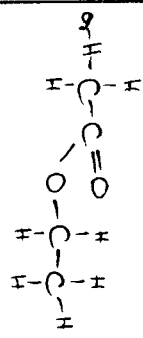
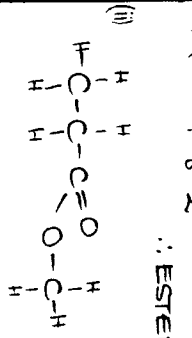
(c) X is acidic \therefore carboxylic acid
 \therefore formula $\text{C}_2\text{H}_4\text{O}_2$
as monofunctional carboxylic acids have molecular formula $\text{C}_n\text{H}_{2n}\text{O}_2$



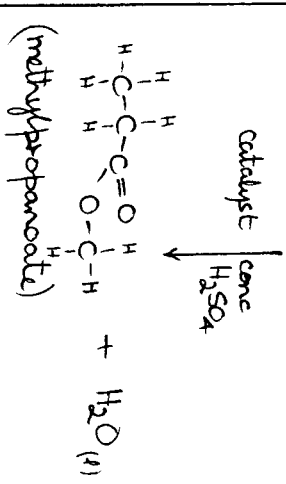
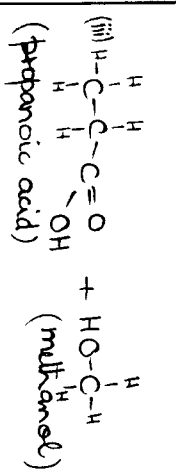
X is ethanoic acid



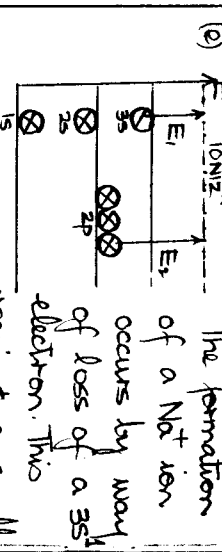
(d) (i) $\text{C}_4\text{H}_8\text{O}_2$: new acidic : ESTER!



others exist too!



Q4. (Continued from next page)

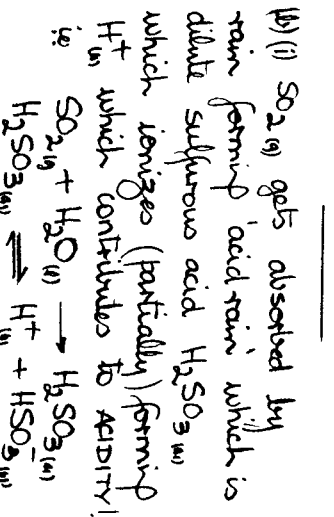


The formation of a Na^+ ion occurs by way of loss of a 3s electron. This requires a small energy E_1 , $\therefore \text{Na} + E_1 \rightarrow \text{Na}^+ + e^-$
The removal of a 2nd e^- is very difficult ($\therefore E_2 = \text{large}$) due to the 2p electrons being much closer to the nucleus (\therefore the 2nd energy shell).
 Na^{2+} doesn't form normally!

QUESTION 4.

(a) The H_2S molecules have very high average molecular translational speeds. This rapid, random movement allows for fast diffusion (\therefore spreading) throughout the room.

NB: The natural tendency towards max. entropy favours this mixing and is accelerated by increased temperatures. ($\therefore E_{\text{kin}} \propto T$ Kelvin)



(ii) Acid rain causes direct damage to buildings, plants, animals, + corrosion of metals, ...
Indirectly the increased $[\text{H}^+]$ dissolves poisonous metals and metal compounds from the soil and allows them to enter ground water (secondary pollutants)
Also, rivers & lakes may become too acidic for life to exist!

(c) PERIOD 2 halogen is F_2

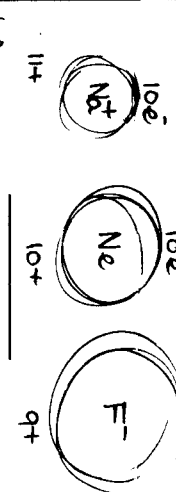
PERIOD 4 alkali metal is K
 $\therefore \text{F} = (\text{He}) 2s^2 2p^5$ (X)
 $\text{K} = (\text{Ar}) 4s^1$ (Y)

(iii) product is KF : bonding type is 'IONIC'

(iii) Element Y (potassium) has lowest E_1 because the 4s¹ outer electron is much further from the nucleus than the outer e⁻ in fluorine and the atomic radii is more significant than nuclear charge (19+ versus 9+)

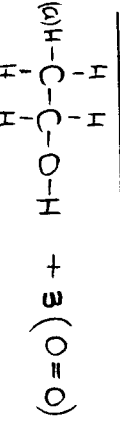
(iv) Z is probably oxygen because K_2O will be a BASIC oxide and $\text{M}(\text{K}_2\text{O}) = 94.2 \text{ g mol}^{-1}$
NOTE $\text{K}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{K}^+ + 2\text{OH}^-$
 \therefore alkaline solution formed!

(d) F^- will have the largest radius because it has only a 9+ nuclear charge attracting the 10e⁻ whereas the Na^+ ion has a 11+ nuclear charge. This 'pulls' the 10e⁻ into a smaller volume. \therefore



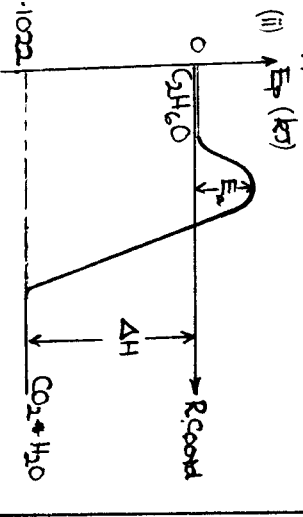
(e) see page 3

QUESTION 5.



BONDS BROKEN	KJ (REQD)
1x(C-C) = 1x348	348 kJ
5x(C-H) = 5x413	2065 kJ
1x(C-O) = 1x357	357 kJ
1x(O-H) = 1x462	462 kJ
3x(O=O) = 3x498	1494 kJ
∴ Total energy reqd = 4726 kJ*	
BONDS FORMED	KJ (RELEASED)
4x(C=O) = 4x744	2976 kJ
6x(O-H) = 6x462	2772 kJ
∴ Total energy release = 5748 kJ*	

Comparing, overall there is a net release of energy (*)(**)
∴ $\Delta H = -1022 \text{ kJ}$

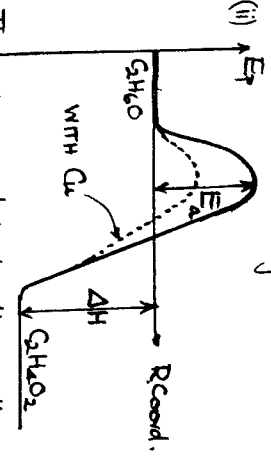


Ethanol ($\text{C}_2\text{H}_5\text{OH}$) has a high enthalpy content and the products (CO_2 & H_2O) have a low enthalpy. Thus, there is a net energy release (EXO) in the combustion ∴ $\text{C}_2\text{H}_5\text{OH}$ has weak bonds & the products have strong bonds!!

(iii) (see EP diagram in part (ii))

The reaction has a fairly high E_a barrier ∴ no collisions at 20°C are effective ∴ these collisions are insufficiently energetic to cross the E_a barrier ∴ at 20°C combustion doesn't occur spontaneously!

(b) (i) $\text{Cu} = \text{catalyst}$



The copper catalyst allows the oxidation reaction to follow an alternate reaction pathway (----) with a lowered E_a ∴ collisions that were previously ineffective now become effective ∴ faster rate. The heat of reaction (ΔH) is not affected by the catalyst.

(c) $100 \text{ MJ} = (100 \times 1000) \text{ kJ} = 1.00 \times 10^5 \text{ kJ}$

∴ $n(\text{C}_2\text{H}_6) \text{ needed} = \frac{1.00 \times 10^5 \text{ kJ}}{2220 \text{ kJ mol}^{-1}} = 45.0 \text{ mol}$

∴ mass $\text{C}_2\text{H}_6 = n(\text{C}_2\text{H}_6) \times M_r(\text{C}_2\text{H}_6) \text{ g} = (45.0 \times 44.0) \text{ g} = 1982 \text{ g} \text{ (1.98 kg)}$

QUESTION 6.

(a) (i) $K = [\text{Pb}^{2+}] \cdot [\text{Cl}^-]^2$

(ii) The larger the value of K , the more the forward reaction is favoured. Conversely, if $K < 0$ ∴ forward reaction doesn't occur to any great extent.

(iii) The number of moles of solid PbCl_2 in 1L is a constant (at a given temp) ∴ $[\text{PbCl}_2(s)] = \text{const}$ ∴ the K_c expression need not have any denominator (apart from 100)

(iv) CHANGE: increase temp
EFFECT: system attempts to decrease temp. (as per LCP)

RESULT: forward reaction is favoured ∴ more $\text{PbCl}_2(s)$ dissolves ∴ $[\text{Pb}^{2+}]$ increases
∴ $K = [\text{Pb}^{2+}][\text{Cl}^-]^2$ increases too.

(b) (i) $[\text{H}_3\text{O}^+] = 10^{-\text{pH}} = 10^{-1.9} = 1.26 \times 10^{-2} \text{ mol/L}$
NOTE: $\text{H}^+ = \text{H}_3\text{O}^+$

(ii) HCl is a strong acid ∴ it is 100% ionized

∴ 1 mol/L HCl gives $[\text{H}^+] = 1 \text{ mol/L}$ ∴ $\text{pH} = 0$

Methanoic acid is weak and only about 1.26% ionized

Thus in 1.0 mol/L HCOOH , the $[\text{H}^+]$ is only $(1.0 \times \frac{1.26}{100}) \text{ mol/L} = 0.0126 \text{ mol/L}$
∴ $\text{pH} = 1.9$

(c) (i) $K = \frac{[\text{H}^+][\text{Bt}^{\ominus}]}{[\text{HBT}]} = 10^{-7}$

(ii) $\text{pH} = 5$ ∴ $[\text{H}^+] = 10^{-5} \text{ mol/L}$
Thus $\frac{10^{-5} [\text{Bt}^{\ominus}]}{[\text{HBT}]} = 10^{-7}$ (all*)
∴ $\frac{[\text{Bt}^{\ominus}]}{[\text{HBT}]} = 10^{-2}$

(iii) This means that the concⁿ of HBT is about 100 times bigger than the concⁿ of Bt^{\ominus} ∴ the predominance of HBT will make the colour YELLOW

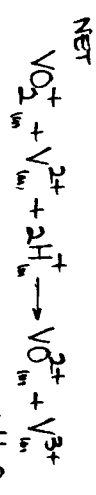
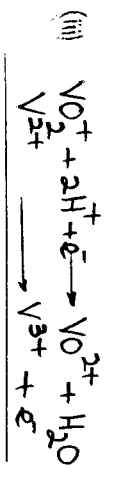
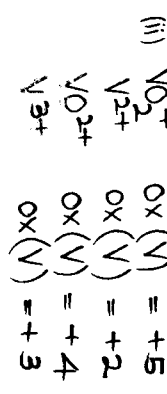
(iv) $\text{pH} = 8$ ∴ $[\text{H}^+] = 10^{-8} \text{ mol/L}$
∴ $\frac{10^{-8} [\text{Bt}^{\ominus}]}{[\text{HBT}]} = 10^{-7}$

∴ Now the $[\text{HBT}]$ is only $\frac{1}{10}$ of the $[\text{Bt}^{\ominus}]$ ∴ the dominant species is Bt^{\ominus} and the colour will now be blue!
(assuming comparable colour intensities)

QUESTION 7

(i) A rechargeable battery is one where the application of an external source of EMF is the discharged battery will cause the reverse reaction to occur. By causing this energy input to force the non-spontaneous reaction to occur, the battery becomes recharged and is called a "secondary" cell.

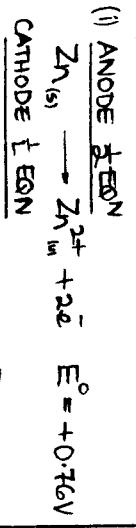
∴ the reactants are regenerated



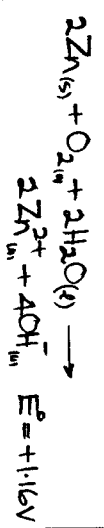
(iv) The recharging will involve the reverse of the above $\frac{1}{2}$ eqn. so the anode (oxidation) $\frac{1}{2}$ eqn will be :-



(b)



(NET)

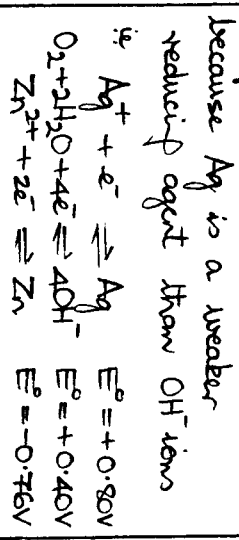


(ii) E° (overall) = +1.16 volt

(iii) mass of Zn = $\left(\frac{A_r(Zn) \times I \times t}{z \times 96500} \right) g$
 \therefore time $t = \left(\frac{\text{mass} \times z \times 96500}{A_r(Zn) \times I} \right) \text{ sec}$

Time = $\frac{4.101 \times 2 \times 96500}{65.4 \times 4.00 \times 10^{-5}}$
 $= 3.03 \times 10^8 \text{ sec}$
 \therefore (time = 9.59 years)

(iv) Ag would not be suitable because Ag is a weaker reducing agent than OH^- ions



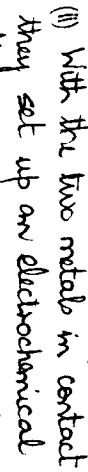
$Ag_{(s)}$ will NOT react spontaneously with O_2 or H_2O but $Zn_{(s)}$ will.



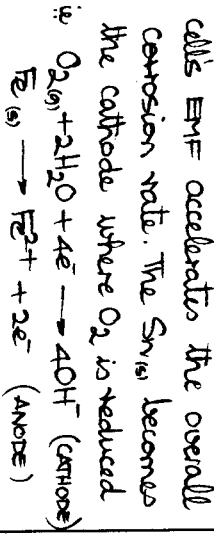
QUESTION 8

(i) corrosion of steel (iron) needs the $Fe_{(s)}$ to come in contact with $O_{2(g)}$ and $H_2O_{(g)}$ in an environment with an electrolyte present. The Sn coating acts as a protective barrier preventing contact between $Fe_{(s)}$ and $O_{2(g)}$ / $H_2O_{(g)}$.

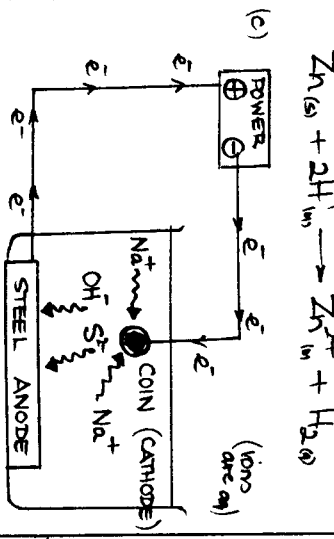
(ii) With the two metals in contact, they set up an electrochemical cell in which the more reactive metal (Fe) corrodes faster than it would on its own because the cell's EMF accelerates the overall corrosion rate. The $Sn_{(s)}$ becomes the cathode where O_2 is reduced



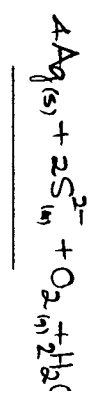
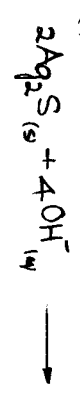
(iii) The Zn galvanizing coating is likely to dissolve (partially) in the food acids, causing toxic zinc salts to contaminate the food.



(c) $Zn_{(s)} + 2H^+ \rightarrow Zn^{2+} + H_{2(g)}$



(ii)



(iii) Probably the gas is $H_{2(g)}$ due to water being reduced at the cathode. $2H_2O(l) + 2e^- \rightarrow H_{2(g)} + 2OH^-(aq)$

(iv) The tarnishing process is a corrosion reaction which is increased in rate by the presence of acidic compounds (∴ acid gases SO_2, SO_3, NO & NO_2 are all associated with industry and motor car pollutants)

∴ industrialised cities are more likely to cause re-tarnishing to occur. A possible reaction: $4Ag_{(s)} + 2S^{2-}_{(aq)} + O_{2(g)} + 2H_2O \rightarrow 2Ag_2S_{(s)} + 4OH^-(aq)$ which is spontaneous (see (ii) above)

(v) Rhodium is a very low reactivity metal (somewhat like platinum) ∴ the Rh coating on the silver coin is a noble metal coating preventing the Ag from coming in contact with the tarnishing (oxidising) agents.