



EXAMINERS' REPORT ON 2001 TERTIARY ENTRANCE EXAMINATION

SUBJECT: CHEMISTRY

STATISTICS

Year	Number Who Sat	Non-Examination Candidates	Did Not Sit
2001	3441	28	157
2000	3623	46	201
1999	3674	32	200

The Examiners' Report is written by the Chief Examiner (or another examiner on their behalf) to comment on matters relating to the Tertiary Entrance Examination in their subject. The opinions and recommendations expressed in this report are those of the Chief Examiner and not necessarily representative of or endorsed by the Curriculum Council.

The Marking Guide provided at the end of this report was prepared for markers and substantially amplified by discussions held in the pre-marking meeting. It is not intended as a set of model answers, and is not exhaustive as regards alternative answers. Some of the answers are less than perfect, but represent a standard of response that the examiners deemed sufficient to earn full marks. Teachers who use this guide should do so with its original purpose in mind.

SUMMARY/ABSTRACT

The 2001 TEE in Chemistry was well received by both teachers and students. Most critics thought that the questions were clear and unambiguous, and that there was good syllabus coverage, with some difficult questions. Teachers appreciated the fact that the stem of each multiple-choice question was shorter and more direct than in previous years. The trend towards simplification of the stem of the multiple-choice questions has continued.

The mean mark for the paper was 56.1% with a standard deviation of 17.8.

This was the first time that candidates were asked to choose an extended answer question from a choice of two, rather than three, questions.

Candidates were again permitted to use graphics calculators in TEE Chemistry in 2001.

Candidates performed well at all skills required of them, although the quality of equation writing was not good. Short Answer Question 1, which required candidates to generate equations for chemical reactions (without prompting within the question such as by the giving of half-equations), was again poorly done. The average mark for Short Answer Question 1 was only 45%.

GENERAL COMMENTS

Organisation

Examining Panel: Mrs Maree Baddock
Dr Stuart Bailey
Mr Mark Ellison (Chief Examiner)

Independent Reviewer: Dr Dion Giles
Final Check Examiner: Mr Ken Quigley
Chief Marker: Dr Stuart Bailey

Markers were provided with a detailed marking guide that was refined at the markers' meeting; this refined marking guide is included as an Appendix.

The examiners are appreciative of the help provided by staff of the Curriculum Council, especially Mrs Kerry Tarrant and Dr Bob Peck.

Structure

The format for the paper was unchanged from last year. The sections were as follows:

• Part 1	30 multiple choice questions	60 marks
• Part 2	10 short answer questions	70 marks
• Part 3	5 calculations	50 marks
• Part 4	1 extended answer question chosen from two possibilities	20 marks
Total for paper		200 marks

Again the data required for the paper was provided on the separate A3 Chemistry Data Sheet.

Candidates' Performance

	Part 1 Multiple Choice Mean (/30)	Reliability*	Part 2 Short Answer Mean (/35)	Part 3 Calculations Mean (/25)	Part 4 Essay Mean (/10)	Total Mean (%)
2001	18.4	0.96	20.0	13.6	3.7	56.1
2000	19.5	0.97	17.8	14.2	5.0	56.6
1999	19.8	0.97	21.8	15.1	4.9	61.7
1998	17.7	0.97	18.6	13.4	4.8	54.4
1997	19.4	0.98	19.0	17.6	5.0	61.0
1996	16.4	0.97	16.7	13.7	3.4	49.9
1995	16.6	0.96	20.8	12.3	4.6	54.4
1994	18.2	0.97	17.9	15.3	4.8	56.2
1993	17.0	0.97	19.2	11.4	4.0	51.6
1992	20.1	0.98	21.8	14.5	4.4	60.8
1991	18.3	0.83	18.2	14.0	4.5	55.0
1990	16.4	0.80	18.7	11.4	4.3	50.5

* Reliability is a measure of a test's internal consistency. It is usually in the range 0.8 to 1.0 for unstandardised tests. The higher, the better. For a given type of test, a low reliability suggests something is wrong.

Some General Comments from the Chief Examiner

In general, the performance of candidates in this examination was rather pleasing. This comment is not based only on the marks scored by candidates, but also on my judgment of the quality of answers in the bundles I marked.

In general, candidates seemed to have mastered the fundamentals of almost all sections of the syllabus and also to have mastered calculations. An observation that I found rather peculiar (as I also did in 2000) was the significant number of candidates who wrote correct equations in Short Answer Question 1, but reverted back to the use of 'molecular' equations when asked to write equations in other questions in Parts 2 and 3! Short Answer questions with means below 50% were Question 1 (on Standard Reactions), Question 4(a) (generating an equation from a given observation), Question 5 (acid base reactions of salts and relating this to pH), Question 8(a) (reaction of a Group I metal with water) and Question 9(b) (explanation of solubility).

This was the seventh year when the rubric covering equation writing was used. The rubric which appears on page 2 of the paper (and is circulated to schools in advance of the TEE) is as follows:

'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 $\text{Ag}^+(\text{aq})$], **molecules** [for example $\text{NH}_3(\text{g})$, $\text{NH}_3(\text{aq})$, $\text{CH}_3\text{COOH}(\ell)$, $\text{CH}_3\text{COOH}(\text{aq})$] or **solids** [for example $\text{BaSO}_4(\text{s})$, $\text{Cu}(\text{s})$, $\text{Na}_2\text{CO}_3(\text{s})$].'

This rubric was designed to remove debate about what should and should not appear in an equation. In general, an equation for a reaction should not be a matter of opinion as to the relative importance of species involved.

A marker suggested that if a candidate wrote 'No reaction' as the answer to all 4 parts of Short Answer Question 1 the candidate should get no marks, even though 'No reaction' is the correct answer to Part (c). The same marker went on to mention that it was a waste of three marks to ask a question that required an answer of 'No Reaction'. I disagree. A student who goes into a high school chemistry laboratory and mixes reagents at random will find, by far the most common outcome is 'no reaction'. If a student approaches a problem by thinking "There will be no reaction unless I can see a reason for reaction" this would be a sensible start to any equation-writing exercise. The student is much more likely to find the correct answer than if the student's starting point is rearranging the symbols of the elements (in the manner of the old 'molecular' equations) with the assumption that something *must* happen. It is unfortunate that the majority of Introductory Chemistry textbooks (including one popularly used for TEE chemistry) still encourage students to learn equation writing by first writing a 'molecular' equation. It is also important for students to STATE an observation of no visible reaction or NVR or equivalent when there is no reaction.

One of the difficulties for many students is that they have never encountered a 'no reaction' in practice. I strongly recommend to teachers that they regularly include questions to which the answer is 'no reaction' in the exercises they set on chemical reactions. By regularly doing this it should help to start students' thinking in terms of what actually happens in the reaction. I also recommend to teachers that they regularly show students examples of a 'no reaction' in the laboratory. 'No reactions' will continue to be included from time to time in Short Answer Question 1.

I suggest that the approach taken by candidates to the equation writing question should be as follows:

Part 2 Question 1 (a)

Copper(II) nitrate is ionic and hence its solution contains Cu^{2+} and NO_3^- ions.

Sodium carbonate is ionic and hence its solution contains Na^+ and CO_3^{2-} ions.

Na^+ and NO_3^- will not react because NaNO_3 is soluble.

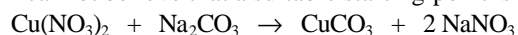
Cu^{2+} and CO_3^{2-} will react because CuCO_3 is insoluble.

It is also necessary to consider pairings of anion with anion and cation with cation (ie. all possible cross-pairings). In this case NO_3^- will not react with CO_3^{2-} nor Cu^{2+} with Na^+ but, in some instances, there is a reaction between ions of like charge. (eg redox reactions)

Answer: $\text{Cu}^{2+} + \text{CO}_3^{2-} \rightarrow \text{CuCO}_3$; and the observation follows (green/blue precipitate forms) because the candidate is focusing on what actually happens.

The argument above is spelt out in some detail (as it was in a previous Examiners' Report). An experienced student will do little more than think about the species dissociating and the new species combining, and write down the answer very quickly. But should a candidate get a wrong answer, at least the teacher makes the correction by focusing on principles.

I cannot believe that a suitable starting-point is writing down the fictional



and then trying to decide which of the formulae needs to be expressed in some other way, and then (assuming you have got that correct) crossing things out if they appear on both sides. And then trying to decide what it all means, if anything, so that you can then commit yourself to an observation.

For the remaining parts of the question, I would argue the case as follows, whether I were doing the question myself, or teaching an Introductory University Chemistry class (or for that matter a high school chemistry class as I will be doing this year).

Part 2 Question 1(b)

Hydrochloric acid is strong and hence its solution contains H^+ and Cl^- .

Sodium sulphite is Na_2SO_3 .

All ionic sulphites react with H^+ (according to $\text{SO}_3^{2-} + 2\text{H}^+ \rightarrow \text{H}_2\text{O} + \text{SO}_2$) and as the SO_3^{2-} is removed from the crystal lattice the Na_2SO_3 dissolves.

Answer: $\text{Na}_2\text{SO}_3 + 2\text{H}^+ \rightarrow 2\text{Na}^+ + \text{SO}_2 + \text{H}_2\text{O}$; and the observation follows (white solid dissolves to give a colourless solution and a pungent gas*) because the student is focusing on the actual outcome.

*A significant number of candidates (incorrectly) described the odour of SO_2 gas as “like rotten egg gas” (ie. like H_2S). It would be worth reinforcing the difference between the odour of H_2S and SO_2 during teaching.

There is no logic in saying that $\text{SO}_3^{2-} + 2\text{H}^+ \rightarrow \text{H}_2\text{O} + \text{SO}_2$ is the important thing that happens. Why is the evolution of a gas more significant than the dissolving of a solid? The sulphite ion can react only because it is released by the solid.

Part 2 Question 1(c)

Hydrochloric acid is strong and hence its solution contains H^+ and Cl^- .

Silver is Ag.

H^+ and Ag will not undergo a redox reaction because the Ag^+/Ag couple has a higher Standard Reduction Potential than the H^+/H_2 couple.

Answer: No reaction.

Part 2 Question 1(d)

Ethanoic acid is CH_3COOH and ethanol is $\text{CH}_3\text{CH}_2\text{OH}$.

Organic acids and alcohols (in the presence of a catalyst and heat) will react to give an ester.

Answer: $\text{CH}_3\text{COOH} + \text{CH}_3\text{CH}_2\text{OH} \rightarrow \text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_3 + \text{H}_2\text{O}$ and the observation follows, because the student is focusing on what changes and what actually happens.

I emphasise: if you teach reactions and equation-writing in terms of the actual species involved, whether ions, molecules, or aggregates of ions, this makes sense, *and* makes the task easier for students.

COMMENTS ON SPECIFIC SECTIONS AND QUESTIONS

Part 1 (Multiple Choice)

The mean raw mark for the multiple choice section of the paper was 36.8 out of 60 (61.4%) with a standard deviation of 9.5 (16%) and a reliability of 0.96. The range of marks on this section was from 6 to 60, and the correlation with the total was 0.88. A more detailed analysis of this section is included in the Appendix. All questions showed a positive discrimination.

Questions which gained less than a 50% correct response are listed below.

Question 8 Only 42% of candidates chose the correct answer (c). The other popular answer was (d) chosen by 26% of candidates. I presume that candidates forgot that $(\text{NH}_4)_2\text{SO}_4$ (unlike $(\text{NH}_4)_2\text{CO}_3$), when dissolved in water does not produce NH_3 .

Question 9 Only 41% of candidates chose the correct answer (c). The other popular answer was (a). This is an instance where the candidate cannot do the question without writing (on the paper).

Question 25 Only 39% of candidates chose the correct answer (b). The most popular answer was (c) chosen by 41% of candidates.

Question 26 Only 32% of candidates chose the correct answer (a).

Question 28 Only 36% of candidates chose the correct answer (a). 30% chose (d). This question was deliberately included to examine the same concepts as in Short Answer Question 7 in the 2000 paper. Many candidates are still ‘hung-up’ on the incorrect idea that water at pH 7 is always defined as neutral. pH 7 only means neutral when the water is at 25°C. At any other temperature, the equilibrium constant for the self-ionisation constant of water will vary. Hence the pH of ‘neutral water’ will change from 7. This doesn’t mean, however, that the water has suddenly become acidic or basic, as $[H^+]$ and $[OH^-]$ concentrations will still be equal to each other at the other temperatures.

Question 29 Only 11% of candidates chose the correct answer (b). The most popular answer was (c) chosen by 60% of students. Candidates who applied the pH algorithm without thinking would have calculated the pH of the HCl solution to be 8. This is obviously a silly answer! This question was used to further illustrate that the self-ionisation of water can contribute to the pH of a water-solution. In particular the self-ionisation of water becomes a more significant contributor to pH as the water-solution becomes more dilute. In $1.00 \times 10^{-8} \text{ mol L}^{-1} \text{ HCl}$, the $[H^+]$ from water is 10-times greater than the $[H^+]$ from the HCl. In this instance the dominant contributor to the pH is the water so assuming a temperature of 25°C (the pH of the solution should be 7). Add a ‘dash’ of HCl and the pH becomes very slightly acidic.

Question 30 Only 19% of candidates chose the correct answer (d). Incorrect responses (a) and (b) were chosen almost equally. Many candidates realised that H_3PO_4 doesn’t completely ionise in a water-solution and so the pH of $1.0 \times 10^{-2} \text{ mol L}^{-1} H_3PO_4$ cannot be 2 – it must be less acidic than pH 2.

It was pleasing to have some very high percentages of correct responses in some multiple-choice questions. In particular, Question 1 (82%, response (a)), Question 10 (81%, response (b)), Question 11 (83%, response (b)), Question 22 (81%, response (a)) and Question 27 (85%, response (a)).

The question where two answers were accepted requires comment.

Question 13 The issue with this question is what you would observe in reality versus what the Standard Reduction Potential table tells you! Even though the oxidation of H_2O to give O_2 is thermodynamically more favourable (in terms of the sign and magnitude of ΔG°) than the oxidation of Br^- to give Br_2 , we don’t see this happen and Br_2 is evolved at the anode. Both responses (a) and (d) were accepted.

Part 2 (Short Answer)

The mean raw mark for Part 2 was 40.0 out of 70 with a standard deviation of 14.2. The correlation with the total was 0.94. The high standard deviation shows a considerable spread of marks, and as usual the Short Answer Section was highly discriminating.

In this section, the mean mark was less than 50% in Questions 1, 5 and 8.

The mean mark was more than 65% in Questions 2, 6, 7, and 10.

1. 12 marks Mean 5.4

Marks for this standard-format question on Standard Reactions have ranged from 4.3 to 6.6 between 1994 and 2001. Part 2 Question 1 has always been answered very badly indeed. Three of the questions were very straight-forward, although part (b) did defeat many candidates. Standard reactions such as the formation of a precipitate based on the given solubility rules which a student should know without having to think much, appeared together with the reaction of a carboxylic acid and an alcohol. It was pleasing to see that many more candidates this year were able to determine where ions should appear in an equation. Some candidates, however, still wrote ‘molecular’ equations first and then attempted to turn them into ‘ionic’ equations. Of particular concern was the significant number of students who used $C_2H_4O_2$ and C_2H_6O as formulae to represent ethanoic acid and ethanol respectively. Are teachers demanding that students express their formulae according to some imagined rule; a good chemist would use the most useful formula, in this case CH_3COOH or CH_3CH_2OH or C_2H_5OH ? The following is a comment made by a very experienced chemistry teacher who has marked TEE Chemistry papers for many years. “I don’t know

why this is perpetuated—it seems one or two teachers “out there” are encouraging students in this meaningless rubbish.”

This is the fifth year when a full observation (and hence a scientific observation) has been required; where candidates wrote the correct equation they seemed to find no difficulty meeting this requirement.

Each of the reactions was dealt with satisfactorily by a significant number of candidates.

2. 12 marks Mean 8.9
This question was well done by most candidates. In a previous Examiners' Report, I made a comment about the expression 'bent-linear'. Again in 2001, some candidates were using 'bent-linear' to describe the molecular geometry of SO_2 . I repeat my comment that 'bent-linear' is nonsense.
3. 7 marks Mean 4.0
This question was well done by most candidates. A comment from a few markers was that some candidates don't take enough care to see what each part of this question was asking – eg did the question ask for a compound, element, monomer or group?
4. 6 marks Mean 3.1
This question was of a new type (first asked in the 2000 paper), but a variation on Short Answer Question 1. In this question, candidates were asked to write an equation consistent with the given observation. This question was not done well. This type of question requires more understanding of the chemistry rather than relying on the rote-learning of equations. Many candidates didn't know what gas limewater is used to test. Even when candidates did know that limewater is used to test for the presence of CO_2 gas, many could not write an equation (especially an 'ionic' equation since many wrote 'molecular' equations) for the reaction between CO_2 gas and limewater. This was particularly disappointing.
5. 7 marks Mean 2.5
This question was poorly done. Many candidates tried to do a pH calculation (when the pH was given in the question). Many candidates forget (or don't understand) that in a water solution (at 25°C) of a salt, the pH will be 7 unless either of the components of the salt will react with the water to produce H^+ or OH^- ions. This is certainly an area that requires attention when teaching acids and bases.
6. 6 marks Mean 4.2
This question was generally well done. A simple attack for this type of problem is 'Will the reagent that is being added introduce any species that appears in the equilibrium equation?' and 'Will the reagent that is being added introduce any species that will *react with* any species that appears in the equilibrium equation?'.
7. 4 marks Mean 2.9
This question was generally well done. This type of question was deliberately repeated in the 2001 paper after our concern from the 2000 paper regarding the number of candidates who stated that you couldn't write an equilibrium constant expression for an equation if there are no gases in the equation!! Although this alternative conception certainly appeared again this year, it was pleasing to note that it occurred much less frequently than in 2000.
8. 5 marks Mean 2.2
Part (a) of this question was poorly done. Many candidates couldn't write an equation for the reaction between water and rubidium metal. Again some candidates were unable to determine where ions should appear in an equation. Many candidates suggested that Rb_2O was formed. Rubidium metal is two positions below sodium in the periodic table so by analogy, rubidium metal should produce hydrogen gas when placed in water (like sodium metal). I wonder what the response would have been if we had used sodium metal instead of rubidium metal?
9. 4 marks Mean 2.2
Part (a) of this question was generally well done. Part (b), however, was poorly done. Many diagrams drawn by candidates didn't illustrate that hydrogen bonding occurs between water and 1,2-ethanediol as well as between molecules of water and between molecules of 1,2-ethanediol.
10. 7 marks Mean 5.2
This question was generally well done.

Part 3 (Calculations)

The mean raw score for Part 3 was 27.2 out of 50 (last year 28.4, and 1999 30.2) with a standard deviation of 11.6 (last year 11.5, and 1999 11.8). The correlation with the total was 0.89.

A high proportion of candidates could do all that was asked of them in the Calculations Section, and scored high marks.

We were again very pleased by candidate performance this year. Many candidates gave quite concise answers to all questions and scored full marks for Part 3.

A concern was the number of candidates who stated in Calculation 3 that they used an “organic formula” programme to determine the empirical formula. These candidates gained very few marks because of the lack of working was shown, it was generally incorrect. Candidates should be discouraged from mindlessly using pre-programmed algorithms to determine empirical formulas. If candidates understand the process involved in determining the empirical formula, they should be able to handle any such question that is given to them. A pre-programmed algorithm is only as good as its writer and only good for the elements that the writer has included. It will take years before we run out of elements for use in empirical formula questions!

1. 8 marks Mean 4.0
2. 12 marks Mean 6.6
3. 12 marks Mean 8.9
4. 11 marks Mean 6.0

Many candidates didn't realise that this question involved the determination of a limiting reagent. For those that did recognise that a limiting reagent may be involved, a comment needs to be made about a particular method, that many candidates used, for calculating the limiting reagent. The method involved some fancy footwork comparing the stoichiometric ratio of $\text{I}_2\text{O}_5/\text{SF}_4$ with the actual ratio of $\text{I}_2\text{O}_5/\text{SF}_4$. This is nonsense. I believe that comparing the actual ratio with the stoichiometric ratio is using a rote-learned ritual. Rather than learn this ritual, candidates should focus on the main point of a limiting reagent – it limits the amount of product. I have used the analogy described below when teaching limiting reagents (and trying to unteach the use of comparing stoichiometric ratio with actual ratio) at the first year university level.

Problems that involve working out the amount of product when the amount of two or more reactants is given presents an added difficulty for candidates. If candidates, however, understand what is actually meant by the limiting reagent (that is, it controls the amount of product formed – this is the *consequence*), then it is a matter of calculating which reactant gives the least amount of product. Instead of having one stoichiometric relationship, you have two.

Using the following contextual example in class to demonstrate the use of limiting reagents in a real-world situation has revolutionised my students' understanding of these calculations.

1 PIECE OF CHEESE + 2 SLICES OF BREAD → 1 CHEESE SANDWICH

The stoichiometric relationship is: 1 : 2 : 1.

Students have access to various amounts of cheese and bread (your choice) with unlimited amount of butter and pickle!

For example if you have 2 slices of cheese and 5 slices of bread, how many cheese sandwiches can be made? Which of the cheese or bread is the limiting reagent? Which of the cheese or bread is in excess?

[Even in the kitchen, the chef suddenly realises that the cheese has run out, even though there is enough bread left over. Cheese is limiting. This is before the chef even realises how many sandwiches have been made. If the chef wants to plan better, the chef should ask, in turn, how much bread will I need for this much cheese? How much cheese will I need for this much bread? You can spice up this question by including pickle!]

Students will soon realise that you can make only 2 cheese sandwiches: the cheese is the limiting reagent with the bread in excess.

When we use limiting reagent principles in a real-world situation (making cheese sandwiches), we don't use some complicated rote-learned ritual or algorithm (eg. comparing the actual ratio with the stoichiometric ratio) to solve them. We use the principle that the limiting reagent controls the amount of product.

The limiting reagent controls the amount of product formed. Always keep this as the focus of the problem.

Avoid fancy magic with stoichiometry! This is not done with real-world examples.

5. 7 marks Mean 2.7

Many candidates this year were again rather slack in their use of significant figures. Many got a wrong final answer as a result of only one or two significant figures in intermediate answers. Candidates should be encouraged to retain at least four significant figures for all intermediate answers and round to the appropriate number of significant figures (as determined by the data) only for the final answer. If necessary, the syllabus should be changed to reflect an adequate dealing with significant figures.

Part 4 (Extended answer)

The mean raw mark for Part 4 was 7.4 out of 20 (last year 10.0, and in 1999 9.9) with a standard deviation of 5.0 (last year 4.3, and in 1999 4.5). The range of marks on this section was from 0 to 20, and the correlation with the total was 0.73 (last year 0.63).

This was the first year that the candidates had to choose one essay topic from a choice of two in Part 4. In keeping with a Syllabus Committee recommendation, one of the essay topics required a more interpretive/application style answer than purely recall of factual information. In addition to conventional extended writing tasks (which will not include questions where recall of information is the main feature), candidates were required to synthesise an extended response to a stimulus passage.

The two most general criticisms of essays that failed to attract a high mark are:

- they are not planned, and
- only some aspects of the topic are dealt with.

Please encourage candidates to spend a little time planning their essays. The examiners have been mindful of this need and reduced the time necessary to complete Parts 1-3. A drawn-up plan, either on the question page or at the beginning of the written pages will not lose candidates marks. And candidates should read each topic carefully, and make certain that they are writing on the topic set, and not on some vaguely similar subject or on only a part of the topic, or some version of the topic of their own generating.

1. Mean 7.7 (Attempted by 25% of candidates)

Candidates were asked to compare and contrast some supplied information about phosphoric acid with the manufacture and uses of sulphuric acid. What was obvious to the markers is that many candidates actually didn't understand what it means to "compare and contrast". It was not sufficient to just repeat the information given in the stimulus passage without then relating and integrating the material with relevant information about the manufacture and uses of sulphuric acid. Many candidates just regurgitated all they knew about the Contact Process (or the Touch Process as one student called it!). This was rewarded with only a few marks.

It would be useful for teachers to set some 'compare and contrast' type extended answer questions to familiarise candidates with what is required. It would be also worth candidates having a look at the model answer for essay 1.

2. Mean 8.4. (Attempted by 65% of candidates)

This essay was well done although many candidates just catalogued all they knew about intermolecular forces and made no mention of solutes and solvents given in the question. Consequently a significant number of candidates scored only 5 marks out of 20 for their effort.

A concern to the examiners was the misconception that dispersion forces and hydrogen bonding are mutually exclusive. They are not. One candidate spoke of “Van der Waals” forces and another believed that NaCl can dissolve in water because aqueous NaCl has active electrons!

In this essay, candidates should have discussed the intermolecular and interionic forces involved in the solutes and solvents. Some candidates choose to integrate this material in to their essay and others discussed the intermolecular forces involved in water and hexane and proceeded to discuss the solubility of each of the solutes in water and hexane.

A key piece of information that wasn't stated by many candidates is that the mixing of two species should be seen as a **competition** between the solute-solute intermolecular forces, the solvent-solvent intermolecular forces and solute-solvent intermolecular forces.

Many candidates only reached the level of establishing that a solvent and solute are, for example, both polar, and hence, without further explanation or justification, claiming that they have proved that the solute must be soluble. This extremely weak argument always came unstuck with AgCl, and even NaCl, which was often claimed as a “polar molecule”, clearly to try to conform with the poor premise of “polar dissolves polar”.

POINTS FOR CONSIDERATION BY THE SYLLABUS COMMITTEE

It is felt that the examination paper was fair and reasonable. In most instances comments about the paper have been favourable.

All questions showed a positive correlation with the total, standard deviations for all questions were high, and the Reliability of the Written Paper was 0.91 with the Reliability of the Entire Paper 0.89; hence the paper seems to have been effective as a ranking tool. It is recommended that the examiners' general approach should be followed in future.

It is also recommended that the practice of relating Calculations questions to real-life or laboratory situations be continued. The Syllabus Committee may want to consider reclassifying the empirical formula calculations. They should not be classified as “organic chemistry”.

We would argue that, following the recommendation in 1998, and in line with the decision that candidates were able to use graphics calculators in this year's examination, we did not set any questions in this paper that were simply recall. All questions involved some application of process skills. Chemistry is about understanding and not about the mindless application of rituals.

Mark Ellison
December 2001

Examining Panel 2001

Chief Examiner: Mr Mark Ellison
Deputy Chief: Mrs Maree Baddock
Third Panel Member: Dr Stuart Bailey

Chief Marker: Dr Stuart Bailey

The attached Appendix contains the Marking Guide issued to markers as modified at the markers' meeting. The guide includes some answers which are not fully correct but which were felt to be worth some credit. This was for the purpose of MARKING, not for providing perfect answers. For this reason the examiners recommend that teachers do not make the Marking Guide available to students. A set of model answers is being prepared by the examiners and these will be available through the Science Teachers' Association of WA.

CHEMISTRY TEE 2001 MARKING GUIDE

APPENDIX

PART 1 (60 MARKS)

Question	Answer	Proportion correct (%)	Question	Answer	Proportion correct (%)
1	a	82	16	b	53
2	d	71	17	c	72
3	c	59	18	b	55
4	b	72	19	b	78
5	d	50	20	d	79
6	a	66	21	d	61
7	d	77	22	a	81
8	c	42	23	c	69
9	c	41	24	b	78
10	b	81	25	b	39
11	b	83	26	a	32
12	d	69	27	a	85
13	a, d	20, 41	28	a	36
14	a	68	29	b	11
15	c	76	30	d	19

PARTS 2 AND 3. Each student should be marked on the answer to the question asked, and on that alone. In general then, a student who gives superfluous correct or even brilliant information should not be rewarded [Another student may have known this but not included it because it wasn't asked]. Similarly, a student who gives superfluous wrong or even ridiculous information should not be penalised. On the other hand, if a student gives two answers to the question asked, one right and one wrong, the student should get half the allocated mark. Where this involves a half-mark, the first half-mark should be rounded up and the next down—with markers retaining this information on a separate sheet (not the Record Sheet) or in their heads.

PART 2 (70 MARKS)

HALF MARKS ARE NOT TO BE RECORDED FOR ANY REASON

1. If the reactants and products are correct but the equation is unbalanced or wrongly balanced, award 1 mark only for the equation.

If ions have not been used where ions are involved, or have been used where free ions are not involved, deduct 1 mark.

No deduction for missing or wrong state symbols.

H_3O^+ can always be used in place of H^+ .

The equation must have some merit (but not necessarily a mark) before a student can earn the observation mark, and the observation mark must relate to species in the equation given by the student.

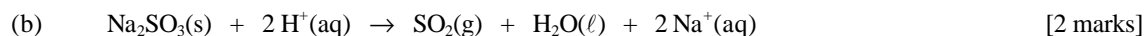
The bulk of the full observation is needed to gain 1 mark.

An incorrect observation which is patently silly should be treated in the same way as no observation. If a student gives an incorrect as well as the correct observation still award 1 mark but carry forward a negative half mark; if a student gives a ludicrous observation as well as the correct observation—so that you feel that the student has no idea at all (for example, in part (a) 'yellow solid forms in purple solution')—award 0 marks.



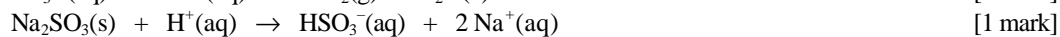
[Blue] solution gives blue (or blue-green) precipitate. [1 mark]

The actual precipitate is close to $\text{Cu}_2(\text{OH})_2\text{CO}_3$.



[White] solid dissolves (to give a colourless solution and) a colourless gas with a sharp (or pungent or unpleasant) odour. Smell of rotten eggs is **not** accepted. [1 mark]

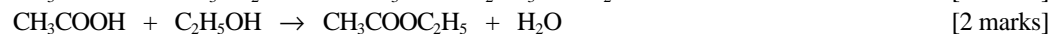
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- (c) No reaction or NR or no visible reaction. [2 marks]

No change observed **or** no visible reaction **or** NVR **or** silvery solid sits in colourless solution. [1 mark]

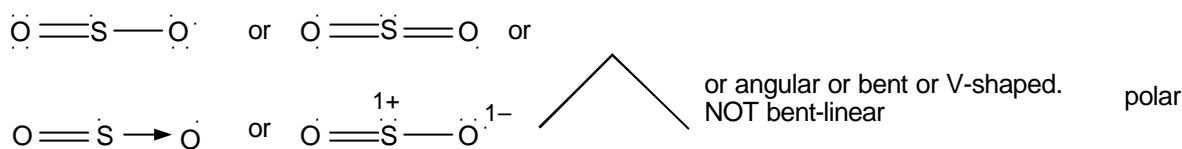
[To gain the 1 mark for the observation, students must correctly give the equation as NR or no reaction or no visible reaction.]



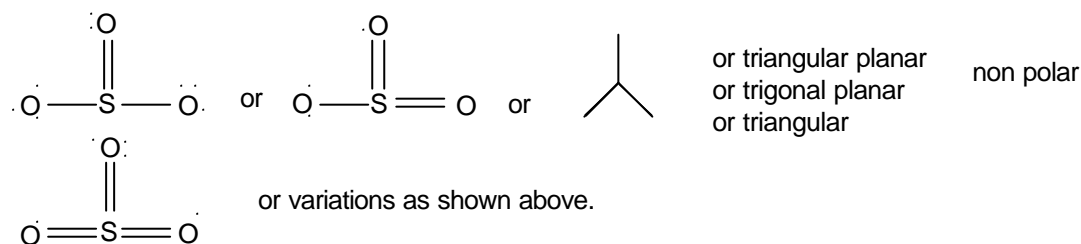
All unambiguous formulae are acceptable.

Sweet odour produced or smells like nail polish remover or paint stripper (etc). [1 mark]

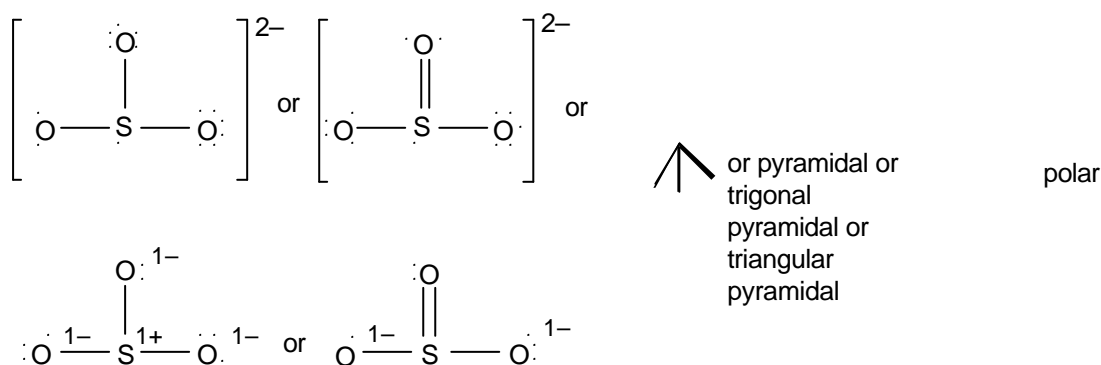
2. 2 marks for each correct structural formula. 1 mark for each correct shape and 1 mark for each correct use of polar or non-polar.



or any other valid contributing structure (as long as each oxygen has an octet). Sulphur can have 8 or 10 electrons.



or any other valid contributing structure (as long as each oxygen has an octet). Sulphur can have 8 or 10 electrons.



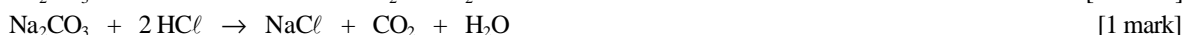
The SO_3^{2-} structure is acceptable even if the overall charge is not indicated. If lone pairs are incorrect in one or more of the three structures, subtract 1 only mark in all.

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3. 1 mark for each correct name or formula. Some examples are given below. **Please watch out for obscure, but correct examples.**

C ₆ H ₆ or CH ₃ CO ₂ ⁻ or any RCO ₂ ⁻ ion or NO ₃ ⁻ or NO ₂ ⁻ or SO ₄ ²⁻ or CO ₃ ²⁻ or SO ₂ or SO ₃ or SO ₃ ²⁻ or CO ₂ or CℓO ₄ ⁻ or CH ₂ =CH-CH=CH ₂ or names. (Not CH ₂ =CH ₂ nor CH ₃ COOH.)
Li ⁺ , K ⁺ , Na ⁺ etc or Mg ²⁺ , Ca ²⁺ etc with Cℓ ⁻ , Br ⁻ , I ⁻ (not F ⁻), NO ₃ ⁻ (not NO ₂ ⁻), SO ₄ ²⁻ (not SO ₃ ²⁻), CℓO ₄ ⁻ . Also AgNO ₃ and KMnO ₄ . Cu ²⁺ , Zn ²⁺ , Fe ²⁺ , Ni ²⁺ , Mn ²⁺ and Co ²⁺ , NH ₄ ⁺ , Al ³⁺ , Cr ³⁺ (and other 3+ cations) salts are acidic . (Note that NH ₄ CH ₃ CO ₂ is neutral). Names are OK.
Diaminopropane (1,1 or 1,2 or 1,3) or propanediamine (1,1 or 1,2 or 1,3) or N≡CCH ₂ C≡N.
Ca ₃ (PO ₄) ₂ or Ca(H ₂ PO ₄) ₂ or CaHPO ₄ or K ₂ SO ₄ or (NH ₄) ₃ PO ₄ or (NH ₄) ₂ SO ₄ or (NH ₄) ₂ HPO ₄ or NH ₄ H ₂ PO ₄ or KNO ₃ or NaNO ₃ or names. If other compounds are given check to see that they are used in fertilisers.
Manganese or Mn or ruthenium or Ru.
Ethene or ethylene or chloroethene or acetoethene or cyanoethene or buta-1,3-diene or formulae or styrene or vinyl acetate or vinyl alcohol or vinyl chloride.
-COOH or carboxylic acid or -SO ₂ OH or sulphonic acids or -OSO ₂ OH. (Unsubstituted phenols do not react with NaHCO ₃ .) Accept nitrated phenols. [Accept a molecule containing the appropriate functional group.]

4.



or



Accept K₂CO₃ or Rb₂CO₃ or Li₂CO₃ or MgCO₃ or BaCO₃ or CaCO₃ or ZnCO₃ or PbCO₃.

Ag₂CO₃ is not accepted.

Accept KHCO₃ or RbHCO₃ or LiHCO₃.

AgHCO₃ is not accepted.

****Anything that suggests that BaCO₃ with H₂SO₄ is unacceptable.****

Pass the gas into lime water / calcium hydroxide solution. [1 mark]

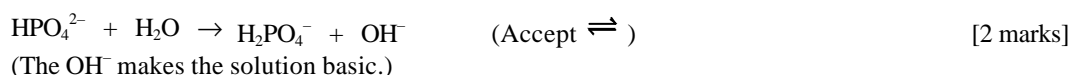
White precipitate forms (which dissolves on prolonged passing of the gas). [1 mark]



Some students may give the equation for the dissolving of CaCO₃ in excess CO₂:

Then CaCO₃ + H₂O + CO₂ → Ca²⁺ + 2HCO₃⁻. This is not worth any additional marks.

5. (a) The HPO₄⁻ ion is a weak base which will react with water as follows [1 mark]



- (b) NH₄⁺ is a weak acid $\text{NH}_4^+ + \text{H}_2\text{O} \rightarrow \text{NH}_3 + \text{H}_3\text{O}^+$ (Accept \rightleftharpoons) [1 mark]

CH₃CO₂⁻ is a weak base

CF

[1

The acidity of the NH₄⁺ ion counters the basicity of the CH₃CO₂⁻ ion.

[2

[Because K_a of NH₄⁺ and K_b of CH₃CO₂⁻ are very close.]

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6.

The use of indicators such as '→' or '←' or 'nc' or '↓' or '↑' are acceptable as part of the explanation.

Experiment and Observation	Explanation
A little concentrated hydrochloric acid is added and the mixture turns more blue and less red.	Added Cl^- ions drive the equilibrium position to the right. [1 mark] Hence the partial loss of red colour and the partial increase in blue colour. [1 mark]
A little silver nitrate solution is added. There is a precipitate and the mixture turns more red and less blue.	Added Ag^+ ions will precipitate Cl^- as AgCl . [1 mark] The removal of Cl^- ions will drive the equilibrium position to the left. [1 mark] Hence the partial loss of blue colour and the partial increase in red colour. [0 marks]
The solution is warmed and the mixture turns more blue and less red.	The reaction must be endothermic. [1 mark] As the solution is warmed the equilibrium will be driven to the right. [1 mark] Hence the partial loss of red colour and the partial increase in blue colour. [0 marks]

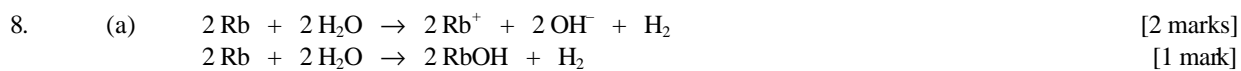
7.
$$K = \frac{[\text{Au}(\text{CN})_2^-]^4 [\text{OH}^-]^2}{[\text{O}_2] [\text{CN}^-]^8} \text{ or } K = \frac{[\text{Au}(\text{CN})_2^-]^4 [\text{OH}^-]^2}{p(\text{O}_2) [\text{CN}^-]^8} \quad [2 \text{ marks}]$$

$$K = \frac{[\text{Au}(\text{CN})_2^-]^4 [\text{OH}^-]^2}{[\text{H}_2\text{O}]^2 [\text{O}_2] [\text{CN}^-]^8} \text{ or } K = \frac{[\text{Au}(\text{CN})_2^-]^4 [\text{OH}^-]^2}{[\text{H}_2\text{O}]^2 p(\text{O}_2) [\text{CN}^-]^8} \quad [1 \text{ mark}]$$

$$K = \frac{[\text{HI}]^2}{[\text{H}_2] [\text{I}_2]} \text{ or } K = \frac{p(\text{HI})^2}{p(\text{H}_2) p(\text{I}_2)} \quad [2 \text{ marks}]$$

1 mark for the inverse. [If both are correct, but inverted 3 marks out of 4.]

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(b) Rapid. [1 mark]

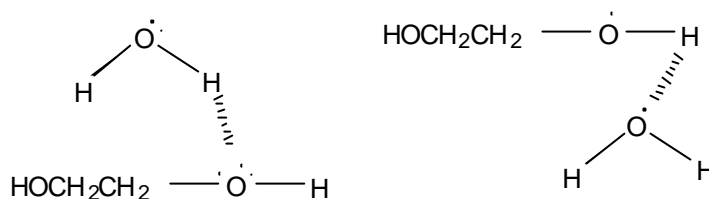
Rb is in the same group as Na which reacts rapidly with water **or** Rb is at the bottom left of the periodic table **or** ionisation energy is low for elements at the bottom left of the periodic table **or** E° for $\text{Rb}^+ + \text{e}^- \rightarrow \text{Rb}$ is large and negative or similar. [2 marks]

[Note: Probably faster than Na because the valence electron is further from the nucleus and more shielded from it, making ionisation energy even less.]

9. (a) Primary or 1°. [1 mark]

(b) Hydrogen bonding occurs between molecules of 1,2-diethanediol and water. [1 mark]

A diagram such as:



[1 mark]

Some mention of mixing (or entropy) such as: “This enables the intermolecular bonding in the mixed state to compete effectively with the intermolecular bonding within the separate components.” **or** some mention of the factors that lead to hydrogen bonding such as: “small sizes of oxygen and hydrogen or large electronegativity difference between oxygen and hydrogen.”

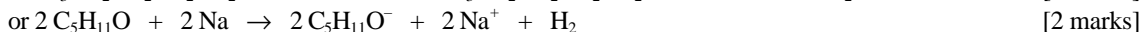
[1 mark]

10. (a) [Only one compound is required but do not penalise if both correct answers are given.]
 [If one or more incorrect answers is given, then 0 marks (no matter what else).]

A or E [1 mark]

B or D [1 mark]

(b) For example:



[Accept the $-\text{ONa}$ form as there is considerable association in this solvent]



[if unbalanced, then 1 mark]

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(c) [3 marks]

slowest reaction	intermediate rate of reaction	fastest reaction
C	B and D	A and E

5 correct answers, 3 marks

4 correct answers, 2 marks

3 correct answers, 1 mark

2 or less correct answers, 0 marks

EXCEPT

1 mark for for A and E B and D C [ie. the reverse order]

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PART 3 (50 MARKS)

In the following calculations use these deductions where appropriate:

Units not given in final answer or wrong units given -1 (maximum of -1 per whole question)

Incorrect usage of significant figures in final answer(s) -1 (maximum of -1 per whole question)

Rounding within part of a calculation which leads to an incorrect answer -1 (maximum of -1 per whole question)

[Hence, where a student gets the wrong answer but the part marks add up to the total mark, 1 mark should be deducted because the student must have made an error.]

Inaccuracy (for example, miscalculation) -1 (maximum of -1 per whole question)

The simple schemes below require some supporting working.

The subsections (a), (b), (i) and so on are to help structure the question; they are meant to assist both the student and the marker. Do not penalise a student for putting an answer in the wrong place or under the wrong heading. Please be on the lookout for this and do not penalise if the working is there somewhere.

The FASTMARK answers still require appropriate working to be shown, and an answer straight out of a cleverly-programmed graphics calculator is worth zero. In general though, you need only make a casual glance to see that there *is* working.

1(a)

	FASTMARK (alternatives)
3 marks	$\frac{2}{5}$ or 0.4 mol, mole or no units

*no working required since the students can answer the question by inspection.

1(b)

	FASTMARK (alternatives)
5 marks	53.68% or 53.68 or 53.7% or 53.7 or an answer between 53.14% and 54.22%
4 marks	8.59% or 8.59 or an answer between 8.50 and 8.68 (if $\frac{2}{5}$ is used instead of $\frac{5}{2}$)

METHOD

$$n(\text{MnO}_4^-) = \frac{24.60}{1000} \times 0.03004$$

$$n(\text{V})_{\text{in } 50 \text{ mL}} = \frac{24.60}{1000} \times 0.03004 \times \frac{5}{2}$$

$$n(\text{V})_{\text{in } 250 \text{ mL}} = \frac{24.60}{1000} \times 0.03004 \times \frac{5}{2} \times \frac{250.0}{50.00}$$

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$$m(V) = \frac{24.60}{1000} \times 0.03004 \times \frac{5}{2} \times \frac{250.0}{50.00} \times 50.94$$

$$\% \text{ by mass of V} = \left. \frac{24.60}{1000} \times 0.03004 \times \frac{5}{2} \times \frac{250.0}{50.00} \times 50.94 \div 0.8765 \right\} \times 100$$

= **53.68%**

PARTMARK (to be added)	
$n(\text{MnO}_4^-) = \frac{24.60}{1000} \times 0.03004 (= 7.390 \times 10^{-4})$	1 mark
$n(V)_{\text{in } 50 \text{ mL}} = \frac{24.60}{1000} \times 0.03004 \times \frac{5}{2} (= 1.847 \times 10^{-3})$	1 mark
$n(V)_{\text{in } 250 \text{ mL}} = \frac{24.60}{1000} \times 0.03004 \times \frac{5}{2} \times \frac{250.0}{50.00} (= 9.237 \times 10^{-3})$	1 mark
For multiplying by 50.94	1 mark
For dividing by 0.8765 and multiplying by 100	1 mark

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2(a)	FASTMARK (alternatives)
2 marks	$\text{K}_2\text{S}_2\text{O}_5 + 2\text{H}^+ \rightarrow 2\text{SO}_2 + \text{H}_2\text{O} + 2\text{K}^+$
1 mark	$\text{S}_2\text{O}_5^{2-} + 2\text{H}^+ \rightarrow 2\text{SO}_2 + \text{H}_2\text{O}$

(b)

	FASTMARK (alternatives)
4 marks	9.4×10^2 g or 937 g or 940 g or an answer between 9.28×10^2 g and 9.46×10^2 g
3 marks	3.7×10^3 g or an answer between 3.71×10^3 and 3.78×10^3 (if $\frac{2}{1}$ is used instead of $\frac{1}{2}$)

METHOD

$$\begin{aligned}
 12000 \text{ L} &= 12000 \times 1000 \text{ mL} \\
 &= 12000 \times 1000 \text{ g} \\
 \therefore (\text{SO}_2) \text{ needed} &= 12000 \times 1000 \times \frac{45}{1000000} \text{ g} \\
 &= 12 \times 45 \text{ g} \\
 &= \frac{12 \times 45}{64.06} \text{ mol} \\
 \therefore n(\text{K}_2\text{S}_2\text{O}_5) \text{ needed} &= \frac{12 \times 45}{64.06} \times \frac{1}{2} \text{ mol} \\
 \therefore m(\text{K}_2\text{S}_2\text{O}_5) \text{ needed} &= \frac{12 \times 45}{64.06} \times \frac{1}{2} \times 222.32 \text{ g} \\
 &= 937 \text{ g} = \mathbf{9.4 \times 10^2 \text{ g}}
 \end{aligned}$$

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PARTMARK (to be added)	
For calculating $12000 \text{ L} = 12000 \times 1000 \text{ g} (= 1.2 \times 10^7 \text{ g})$	1 mark
$n(\text{SO}_2) \text{ needed} = \frac{12 \times 45}{64.06} \text{ mol} (= 8.430 \text{ mol})$	1 mark
$n(\text{K}_2\text{S}_2\text{O}_5) \text{ needed} = \frac{12 \times 45}{64.06} \times \frac{1}{2} \text{ mol} (= 4.215 \text{ mol})$	1 mark
For multiplying by 222.32	1 mark

(c)

	FASTMARK
2 marks	$\text{SO}_2 + \text{H}_2\text{O}_2 \rightarrow \text{SO}_4^{2-} + 2 \text{H}^+$

(d)

	FASTMARK (alternatives)
4 marks	48 ppm or 48 or an answer between 47.48 and 48.44 ppm
3 marks	1.9×10^2 ppm or 192 ppm or an answer between 1.90×10^2 and 1.94×10^2 ppm (if $\frac{2}{1}$ is used instead of $\frac{1}{2}$)
3 marks	96 ppm or an answer between 95 and 97 ppm (if $\frac{1}{1}$ is used instead of $\frac{1}{2}$)

METHOD



6.51 mL of $0.0092 \text{ mol L}^{-1} \text{OH}^- \equiv 40.00 \text{ mL wine}$

$\text{no of mol of OH}^- = \frac{6.51}{1000} \times 0.0092$	$\text{no of mol of H}^+ = \frac{6.51}{1000} \times 0.0092$
--	---

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$$n(\text{SO}_2) = \frac{6.51}{1000} \times 0.0092 \times \frac{1}{2}$$

$$\therefore \text{mass of SO}_2 = \frac{6.51}{1000} \times 0.0092 \times \frac{1}{2} \times 64.06$$

$$\frac{6.51}{1000} \times 0.0092 \times \frac{1}{2} \times 64.06 \text{ g SO}_2 \text{ in 40 g of wine}$$

$$\frac{6.51}{1000} \times 0.0092 \times \frac{1}{2} \times 64.06 \times \frac{1000000}{40} \text{ g SO}_2 \text{ in 1 kg of wine}$$

$$= 47.96$$

$$= \mathbf{48 \text{ ppm}}$$

PARTMARK (to be added)	
no of mol of $\text{OH}^- = \frac{6.51}{1000} \times 0.0092 = \text{no of mol of H}^+ (= 5.989 \times 10^{-5})$	1 mark
$n(\text{SO}_2) = \frac{6.51}{1000} \times 0.0092 \times \frac{1}{2} (= 2.995 \times 10^{-5})$	1 mark
For multiplying by 64.06	1 mark
For $\frac{1000000}{40}$	1 mark

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3(a)

	FASTMARK (alternatives)
8 marks	FeC ₁₄ H ₁₄ O ₂

METHOD



$$\begin{array}{l}
 \text{mass C} = 3.037 \times \boxed{} \\
 = 0.8288 \text{ g}
 \end{array}
 \qquad
 \begin{array}{l}
 \text{mass H} = 0.615 \times \boxed{} \\
 = 0.06882 \text{ g}
 \end{array}$$

$$\text{mass Fe} = 0.392 \times \frac{55.85 \times 2}{159.7} = 0.2742 \text{ g}$$

	Fe	C	H	O
mass (g)	0.2742	0.8288	0.06882	1.3270 - (0.2742 + 0.8288 + 0.06882) = 0.1552
÷ At Wt	55.85	12.01	1.008	16.00
= (mol)	0.004909	0.06901	0.06827	0.009699
÷ smallest no (0.004909)	1	14.06	13.91	1.98
Round	1	14	14	2

PARTMARK (to be added)		
mass of C = 3.037 × $\boxed{}$ = 0.8288 g , <u>or</u> percentage of C = 3.037 × $\boxed{}$ × $\frac{100}{1.3270}$ (= 62.45%)		1 mark

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mass of H = $0.615 \times \boxed{}$ = 0.06882 g, <u>or</u> percentage of H = $0.615 \times \boxed{} \times \frac{100}{1.3270}$ (= 5.186%)	1 mark
mass of Fe = $0.392 \times \frac{55.85 \times 2}{159.7}$ = 0.2742 g, <u>or</u> percentage of Fe = $0.392 \times \frac{55.85 \times 2}{159.7} \times \frac{100}{1.3270}$ (= 20.66%)	1 mark
mass of O = $1.3270 - (\text{student's mass of C} + \text{student's mass of H} + \text{student's mass of Fe})$ (correct value 0.1552 g), <u>or</u> % of O = $100 - (\text{student's \% age of C} + \text{student's \% age of H} + \text{student's \% age of Fe})$ (correct value 11.71%)	1 mark
no of mol C = $\boxed{}$ plus no of mol H = $\boxed{}$, plus no of mol Fe = $\frac{\text{students mass of Fe}}{55.85}$, <u>or</u> no of mol C = $\boxed{}$ plus no of mol H = $\boxed{}$, plus no of mol Fe = $\frac{\text{students \% age of Fe}}{55.85}$	2 marks
for dividing by the smallest number of moles	1 mark
for correct rounding to give empirical formula	1 mark

(b)

	FASTMARK
3 marks	2.7×10^2 or 270 or 272 or an answer between 269 and 274. No unit or g or g mol^{-1} are OK.

METHOD

The gas at 303 K and 98 kPa occupies 71 mL

$$298 \text{ K and } 101.3 \text{ kPa occupies } 71 \times \frac{298}{303} \times \frac{98}{101.3} = 67.55 \text{ mL}$$

1 mol gas at 298 K and 101.3 kPa occupies 24470 mL

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$$\frac{67.55}{24470} = 0.002761 \text{ mol gas at 298 K and 101.3 kPa}$$

$$\therefore n(\text{X}) = 0.002761 \times \frac{1}{2} = 0.001380$$

$$0.001380 \text{ mol X} = 0.375 \text{ g}$$

$$\therefore 1 \text{ mol X} = \frac{0.375}{0.001380} = 271.7 = \mathbf{272}$$

OR

The gas at 303 K and 98 kPa occupies 71 mL

$$273 \text{ K and 101.3 kPa occupies } 71 \times \frac{273}{303} \times \frac{98}{101.3} = 61.89 \text{ mL}$$

1 mol gas at 273 K and 101.3 kPa occupies 22410 mL

$$\frac{61.89}{22410} = 0.002761 \text{ mol gas at 273 K and 101.3 kPa}$$

$$\therefore n(\text{X}) = 0.002761 \times \frac{1}{2} = 0.001380$$

$$0.001380 \text{ mol X} = 0.375 \text{ g}$$

$$\therefore 1 \text{ mol X} = \frac{0.375}{0.001380} = 271.7 = \mathbf{272}$$

OR

$$PV = nRT$$

$$? n(\text{gas}) = \frac{PV}{RT} = \frac{98 \times 0.071}{8.315 \times 303}$$

$$\text{Hence } n(\text{X}) = \frac{1}{2} \times \frac{98 \times 0.071}{8.315 \times 303}$$

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Hence $\frac{98 \times 0.071}{8.315 \times 303} \times \frac{1}{2} \text{ mol(X)} = 0.375 \text{ g}$
 ? 1 mol = $0.375 \div \frac{98 \times 0.071}{8.315 \times 303} \times \frac{1}{2} = 0.375 \times \frac{8.315 \times 303}{98 \times 0.071} \times 2 = 272$

OR

$$\text{MWt} = \frac{mRT}{PV}$$

$$= \frac{0.375 \times 8.315 \times 303}{98 \times 0.071} \times 2 = 272$$

FOR THE MOLAR VOLUME APPROACH

PARTMARK (to be added)	
for recognising that the answer is 0.375 multiplied by <i>something</i>	1 mark
for the $\frac{24470}{71}$ or $\frac{22410}{71}$ factor	1 mark
for the $\frac{303}{298}$ or $\frac{303}{273}$ factor	1 mark

FOR THE FORMULA APPROACH (far more likely to be used by students with an incorrect answer)

PARTMARK (to be added)	
for MWt = <input type="text"/> OR BOTH OF PV = nRT AND MWt = <input type="text"/>	1 mark
for the correctly chosen values of THREE of m, R, T, P, and V (even if the formula mark has not been earned)	1 mark
for the correctly chosen value of ONE more of m, R, T, P, and V (even if the formula mark has not been earned)	1 mark

Note: the volume of gas is given in the question to 2 significant figures because in an experiment it would be impossible to measure any more accurately; thus in this instance 2 significant figures is the appropriate accuracy for the answer, but 3 significant figures is accepted. It might be considered to be pedantic to quote the answer as 2.7×10^2 but students who write this certainly know their stuff.

(c)

	FASTMARK
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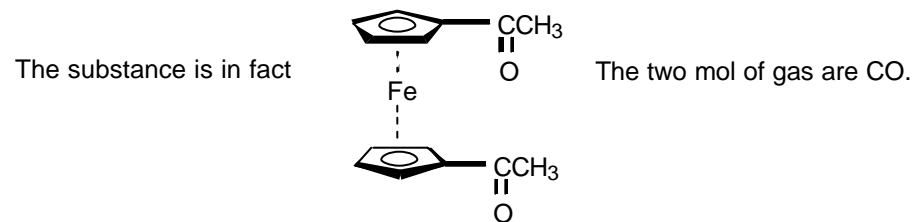
1 mark	FeC ₁₄ H ₁₄ O ₂
--------	--

METHOD

MWt of FeC₁₄H₁₄O₂ = (1 × 55.85 + 14 × 12.01 + 14 × 1.008 + 2 × 16) = 270.102 ~ 272.

? Molecular formula = empirical formula = FeC₁₄H₁₄O₂

PARTMARK (to be added)	
correct calculation of empirical formula weight from student's answer in (a)	1 mark
Intelligent comparison with student's molecular weight from (b); even to the point of saying that the empirical formula and the molecular weight cannot be matched and the student must have made an error.	1 mark



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4(a)	FASTMARK (alternatives)
5 marks	5.81 L or an answer between 5.751 L and 5.867 L

METHOD

$$\text{no of mol I}_2\text{O}_5 = \frac{32.07}{333.8} = 0.09608 \text{ mol}$$

The SF₄ gas at 349 K and 120 kPa occupies 6.02 L

$$273 \text{ K and } 101.3 \text{ kPa occupies } 6.02 \times \frac{273}{349} \times \frac{120}{101.3} = 5.578 \text{ L}$$

1 mol gas at 273 K and 101.3 kPa occupies 22.410 L

$$\frac{5.578}{22.410} = 0.2489 \text{ mol SF}_4$$

then

EITHER



0.2489 mol of SF₄ would require $0.2489 \times \frac{2}{5} = 0.09956$ mol I₂O₅ which **is not** available (0.09608 < 0.09956). Hence I₂O₅ is the limiting reactant.

The following two methods for calculating the limiting reagent should (grudgingly) be accepted. I believe that comparing the actual ratio with the stoichiometric ratio is using a rote-learned ritual. Rather than learn this ritual, students should focus on the main point of a limiting reagent—it limits the amount of product.

OR

ratio from equation = $5 / 2 = 2.5$

while actual ratio = $0.2489 / 0.09608 = 2.59$
Hence I₂O₅ is the limiting reactant.

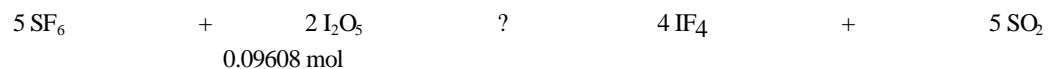
OR

ratio no of mol I₂O₅ / no of mol SF₄ = $2 / 5 = 0.4$

while actual ratio = $0.09608 / 0.2489 = 0.386$

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Hence I_2O_5 is the limiting reactant.



Since I_2O_5 is the limiting reactant, $\frac{32.07}{333.8} = 0.09608$ mol will react, to produce $0.09608 \times \frac{5}{2} = 0.2402$ mol SO_2 .

1 mol SO_2 at 273 K and 101.3 kPa occupies 22.410 L

0.2402 mol SO_2 at 273 K and 101.3 kPa occupies 0.2402×22.410 L = 5.383 L

at 349 K and 120 kPa occupies $5.383 \times \frac{349}{273} \times \frac{101.3}{120} = 5.81$ L

OR

PV = nRT

$$? \ V(SO_2) = \frac{nRT}{P} = \frac{0.2402 \times 8.315 \times 349}{120} = 5.81 \text{ L}$$

PARTMARK (to be added)	
no of mol $I_2O_5 = \frac{32.07}{333.8} = 0.09608$	1 mark
no of mol $SF_4 = 0.2489$	1 mark
no of mol of SO_2 produced = student's no of mol of $I_2O_5 \times \frac{5}{2}$ (correct value = 0.2402 mol)	1 mark

EITHER

Vol of SO_2 at STP = student's no of mol of $SO_2 \times 22.410$ (correct value = 5.383 L)	1 mark
Vol of SO_2 produced = student's no of mol of $SO_2 \times 22.410 \times \frac{349}{273} \times \frac{101.3}{120}$ (correct value = 5.81 L)	1 mark

or

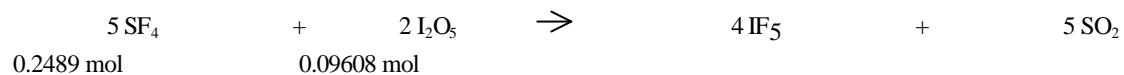
Vol of SO_2 produced = student's no of mol of $SO_2 \times \frac{8.315 \times 349}{120}$ (correct value = 5.81 L)	2 marks
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4(b)

	FASTMARK (alternatives)
6 marks	No I ₂ O ₅ , 0.940 g SF ₄ or an answer between 0.931 g and 0.949 g, 42.6 g IF ₅ or an answer between 42.2 g and 43.1 g, 15.4 g SO ₂ or an answer between 15.2 g and 15.5 g

METHOD



Since I₂O₅ is the limiting reactant, it is consumed entirely, so that none is left.

	number of mole	Molecular weight (g mol ⁻¹)	Mass (g)
I ₂ O ₅	0		0
SF ₄	0.2489 - (5/2 × 0.09608) = 0.008700	108.06	0.940
IF ₅	0.09608 × 4/2 = 0.1922	221.9	42.6
SO ₂	0.09608 × 5/2 = 0.2402	64.06	15.4

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PARTMARK (to be added)	
For stating that since I_2O_5 is the limiting reactant, it is consumed entirely, so that none is left.	1 mark
no of mol IF_4 = student's no of mol $I_2O_5 \times 4/2$ (correct value 0.1922 mol)	1 mark
no of mol SO_2 = student's no of mol $I_2O_5 \times 5/2$ (correct value 0.2402 mol)	1 mark
no mole SF_4 = student's no of mol $I_2O_5 - (5/2 \times \text{student's no of mol } I_2O_5)$ (correct value = 0.008700)	1 mark
For the multiplying by the correct molecular weights of SF_4 , IF_5 and SO_2 . [If a molecular weight is incorrect, then 1 mark]	2 marks

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5(a)

	FASTMARK (alternatives)
5 marks	2 or 2 active H atoms.

METHOD

1 mole of CH₄ at 298 K and 1.0 atm occupies 24470 mL

$$\frac{43}{24470} = 0.001757 \text{ mol of CH}_4 \text{ at 298 K and 1.0 atm occupies 43 mL}$$

OR

$$PV = nRT$$

$$? n(\text{CH}_4) = \frac{PV}{RT} = \frac{1.0 \times 0.043}{0.08206 \times 298} = 0.001758$$

$$\text{MWt}(\text{C}_8\text{H}_8\text{O}_3) = 152.144$$

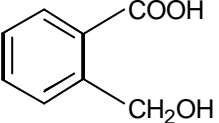
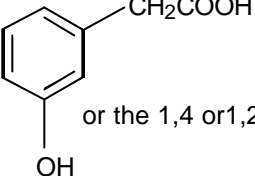
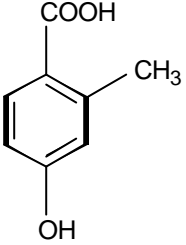
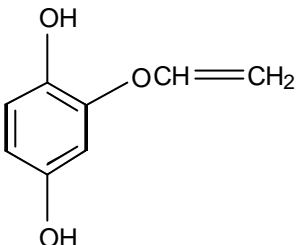
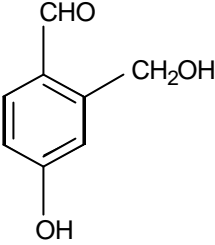
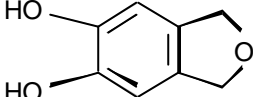
$$n(\text{C}_8\text{H}_8\text{O}_3) = \frac{0.1345}{152.144} = 0.0008840$$

$$n(\text{active H atoms}) = \frac{0.001757}{0.0008840} = 1.99 = 2 \ \backslash \ \mathbf{2 \text{ active H atoms}}$$

PARTMARK (to be added)	
For calculating the mole of CH ₄ = 0.001758	1 mark
For calculating MWt (C ₈ H ₈ O ₃) = 152.144	1 mark
n(active H atoms) = student's mole of CH ₄ ÷ student's mole of C ₈ H ₈ O ₃	2 marks
By rounding up to 2 and making a comment that this is the number of active H atoms.	1 mark

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5(b)

	FASTMARK
2 marks	<div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;">  <p>or the 1, 3 or 1,4 disubstituted isomer</p> </div> <div style="text-align: center;">  <p>or the 1,4 or 1,2 disubstituted isomer.</p> </div> </div> <div style="display: flex; justify-content: space-around; align-items: center; margin-top: 20px;"> <div style="text-align: center;">  </div> <div style="text-align: center;">  </div> <div style="text-align: center;">  </div> </div> <div style="text-align: center; margin-top: 20px;">  </div> <p style="text-align: center; margin-top: 20px;">plus any other aromatic compound of molecular formula $C_8H_8O_3$ with 2 active H atoms.</p>
1 mark	An aromatic compound of molecular formula $C_8H_8O_3$ with other than 2 active H atoms.
0 marks	For any answer based on any other molecular formula.

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PART 4 (20 MARKS)

The rubric at the beginning of this section states that marks are to be awarded principally for the relevant chemical content of the answers but some marks can also be gained for clarity in arranging a reasonable amount of material in a coherent form. Answers should be presented in about 1½ - 2 pages.

Please recognise that the numbers of pages referred to above and below refer to average handwriting, and make your judgments accordingly. Also, you should make adjustments for commodious paragraphing and spaces left by students in their texts. [Despite the problems associated with referring to *pages* in the rubric, examiners have chosen not to prescribe essay lengths by the much more explicit *numbers of words*, because it is feared that students would then consume time in word-counting.]

Prior to the sitting of the TEE, you have been sent copies of essays that scored high marks in 2000. It is essential that you realise that you must not seek out the essay **you** would have written before you give full marks. There are three key points

- * these are Year 12 students, not university Science Graduates;
- * students are writing under examination conditions; and
- * since one can probably write 10 pages on each of the topics, quite different approaches to a particular essay must be accepted when only 2 pages are required.

In general, then, for full marks we are looking for two pages of

- * good chemistry,
- * on the topic given,
- * written in reasonable English (without too much concern on our part for spelling),
- * with some reasoning shown (for example, an inter-relating of evidence and theory),
- * with a beginning, a middle, and an end, and
- * either no errors, or errors which are trivial, or errors which are thought to be slips.

Diagrams, graphs, drawings, schematic outlines, and so on, should be included if this is an appropriate method for getting the message across.

When applying the following, please refer to the 2nd paragraph (above) on the meaning of a 'page'.

In general, if there is $\frac{3}{4}$ of a page of chemistry (and nothing else or $\frac{3}{4}$ of a page of waffle or rubbish) the essay should be marked out of 10.

However, if the $\frac{3}{4}$ of a page of chemistry is brilliant, maybe up to 14.

Similarly, if there is $1\frac{1}{2}$ pages of chemistry, but so padded out and repetitive that the material could have been covered in $\frac{3}{4}$ of a page, the essay should be marked out of 10.

If a (good) student appears to have run out of time, and gives a brilliant 1 page outline of an essay (in note form), maybe up to 14.

For 2 pages of brilliant stuff and 1 page of waffle (for example, irrelevant but correct material), 19.

For 2 pages of brilliant stuff and 1 page of garbage (for example, incorrect chemistry), 13 (two thirds of the marks).

For 2 pages of brilliant stuff and 2 pages of garbage, 10 (half the marks).

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In principle you should focus more on the good material than on the bad—the essay gives the student the opportunity to tell us what he or she knows. Please give credit for good sensible chemistry, and discount student aberrations. But if a student writes rubbish, which shows a lack of knowledge and understanding of chemistry, the student must be penalised. Simply because there are few or no good essays on a topic is not a reason for giving a top mark to an unsatisfactory essay.

Reasoning and argument are important; a “stamp-collector’s” essay should be marked out of 14.

A student must justify what he or she writes about. If the essay is right on the topic there is no problem, but if the essay deviates, a justified account is worth more than one where the student simply launches into irrelevancies.

BE CAREFUL WHEN ASSESSING UNUSUAL ESSAYS OR ESSAYS WHICH CONTAIN UNUSUAL MATERIAL. In the past there have been instances where students have scored close to full marks for Sections 1 to 3 but a very very poor mark in the Essay. When the essay has been reviewed, it has appeared to be an outstanding essay but pitched at university level. In one instance an essay was awarded 5, while the Chief Examiner later assessed the essay at 19 (the only fault being the lack of a beginning and an end). Some markers mark each paper right through, but many markers mark the Sections separately and may not notice when an otherwise outstanding student writes an essay which scores poorly. When you are recording your marks, please re-check any essays of otherwise outstanding students, if it is possible that you marked the essay down simply because it was unconventional.

ESSAY 1

This question asks students to compare and contrast the manufacture and uses of sulphuric acid with the information supplied about phosphoric acid. A requirement therefore would be to give a brief outline the Contact Process. This should be worth 7 marks out of the 20 marks.

Pure H_2SO_4 is a liquid at room temperature; pure H_3PO_4 is a solid at room temperature. This can be related to the intermolecular forces. *This difference in boiling point could be attributed to the three O–H groups in H_3PO_4 compared to two O–H groups in H_2SO_4 .*

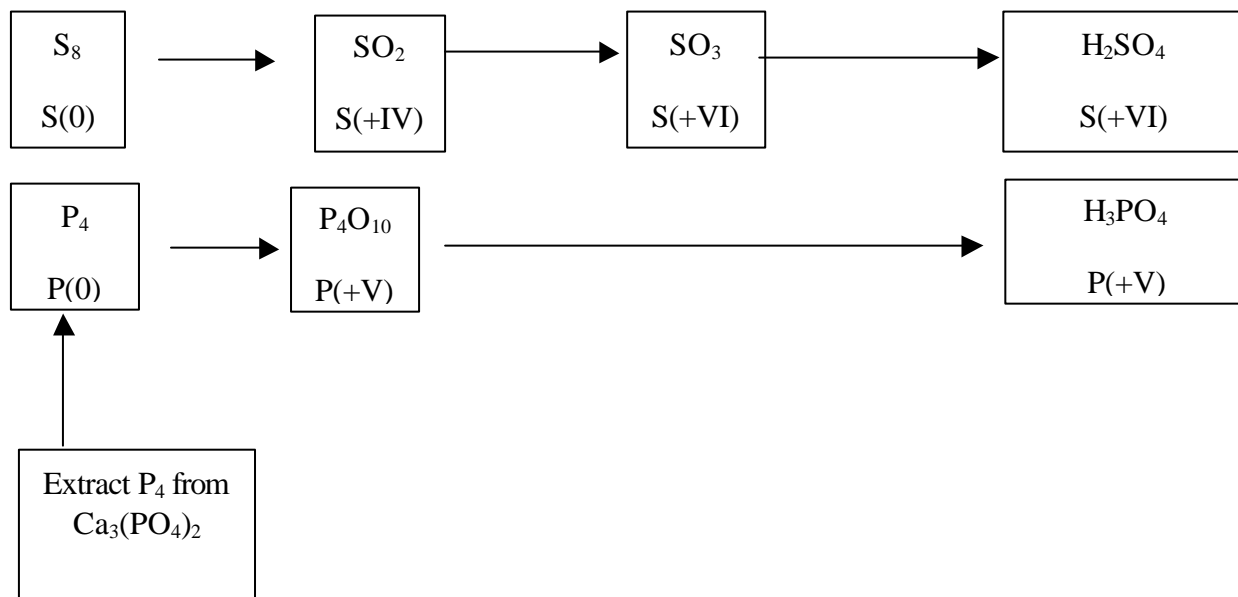
H_3PO_4 is a moderately strong triprotic acid whereas H_2SO_4 is a strong diprotic acid. *Equations could be given here.*

Concentrated H_2SO_4 is an excellent dehydrating agent and reacts with water in a highly exothermic process. Concentrated H_3PO_4 is a dehydrating agent, although its anhydride (P_4O_{10}) is a powerful one.

The phosphorus in H_3PO_4 is used in fertilisers whereas H_2SO_4 is used mainly as an industrial acid.

H_3PO_4 is used in anti-rust by putting coating on the Fe.

In the production of H_3PO_4 the P_4 has to be extracted (by reduction) from the starting material [$\text{Ca}_3(\text{PO}_4)_2$] before oxidation to P_4O_{10} . *The appropriate equations should be given.* The P_4O_{10} [P(+V)] is then converted into H_3PO_4 [P(+V)]. *An appropriate equation should be given.* This is in contrast to the production to H_2SO_4 in which the raw material, S_8 , is oxidised to SO_2 [S(+IV)], then to SO_3 [S(+VI)] and finally the SO_3 is converted into H_2SO_4 [S(+VI)]. *The appropriate equations should be given.* Alternatively the SO_2 can be obtained by the roasting of a sulphide ore, eg CuS or PbS or FeS_2 . *[A good answer might include the equation for the roasting of the sulphide ore.]* The production of H_2SO_4 doesn't have the pre-extraction of the sulphur from the ore. This can be illustrated in the following diagram. If students discuss oxidation state, the following would also be a good summary.



The conversion of SO_2 into SO_3 is slow at room temperature and therefore requires the presence of a catalyst whereas the conversion of P_4 into P_4O_{10} is spontaneous at room temperature. [Activation energy diagrams could be drawn.]

In the production of both H_3PO_4 and H_2SO_4 all steps are exothermic and so heat is a valuable by-product. [Reaction pathway diagrams could be drawn.]

ESSAY 2

BE ALERT FOR THE PREPARED, GRAPHICS CALCULATOR PRODUCED INTERMOLECULAR FORCES ESSAY!!

As mentioned in the rubric to essay 2, students must discuss the intermolecular and interionic forces involved in the solutes and solvents. A student may choose to integrate this material in to their essay or they may discuss the intermolecular forces involved in water and hexane and proceed to discuss the solubility of each of the solutes in water and hexane.

A student who does not explain the specific data given in the table should not score more than 5 marks out of 20 no matter how brilliant the material.

The following points **must** be made.

2. The intermolecular forces involved in hexane are relatively weak dispersion (or London or induced dipole) forces.
- The intermolecular forces involved in water is based on the much stronger hydrogen bonding.
3. The mixing of two species should be seen as a competition between the solute-solute intermolecular forces, the solvent-solvent intermolecular forces and solute-solvent intermolecular forces.

A good answer would address the following point:

- Students should also give an explanation that species tend to mix.

Some ideas as to what students might write about follow:

Consider water and methanol (CH_3OH).

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Water is quite structured because of the strong hydrogen bonds which link its molecules. There is also a (weaker) hydrogen-bond structure in methanol.

Water and methanol molecules form hydrogen bonds with each other as well as among themselves. Hydrogen bonds between water and methanol are driving forces for **mixing**. These, *[together with the tendency to disorder which always drives mixing]*, result in water and methanol being miscible with each other in all proportions. On the other hand, 1-pentanol is a larger molecule than methanol. Although the hydrogen bonds between water and 1-pentanol are still driving forces for **mixing**, the dispersion forces in 1-pentanol are over a significant area. These dispersion forces cannot compete effectively with the hydrogen bonding between water molecules, and hence water and 1-pentanol are only partially miscible.

Decane and water on the other hand do not mix appreciably. Decane is non-polar and its molecules are linked only by relatively weak dispersion forces. The only links which decane molecules can form with water molecules are also dispersion forces, which are even weaker than decane-decane dispersion forces because the water molecule is so small. Mixing is unlikely to occur because the hydrogen bonded structure of water, which would have to be disrupted to accommodate the decane. Methanol and 1-pentanol have weaker hydrogen bonding than water but stronger dispersion forces. As a result of the increased dispersion forces both methanol, and to a much greater extent, 1-pentanol have a tendency to mix with hexane.

Decane, however, mixes readily with hexane. All the forces both in the separate liquids and in the mixture are relatively weak as they do not involve significant polar interactions, *(and the drive to disorder)* is able to ensure good mixing.

The competitive considerations which govern the miscibility of liquids also govern the solubility of solids. In solids, however, we are considering the strength of the crystal lattice. However, we can make some general observations:

Within ionic solids, forces vary in strength from the very weak (eg NaCl is soluble in water but not in hexane) to strong enough to resist appreciable dissolution in any liquid (eg AgCl is insoluble in both water and hexane). The interactions between the solute (ions) and the solvent may also vary in strength. It is the competition between this attraction and the strength of the ionic lattice that determines solubility.

In solids consisting of stacked molecules, like sugars (eg *allose*), the strength of the forces holding the molecules to each other depends on the nature of the forces. *Allose* consists of molecules containing many polar -OH groups, and hydrogen bonding is an important cohesive force. *Allose* is a small molecule and so the dispersion forces are therefore not that considerable. It is these forces within solids which, along with the forces within the solvent, **resist** dissolution.

The major driving forces **promoting** dissolution are *solvation* and *(the tendency to disorder.)* Solvation is the formation of attractions between the solvent molecules and the solute molecules or ions. It is usually a strong force, especially if hydrogen bonding is involved or if the species solvated has a high positive or negative charge density. Water is a very powerful solvent for most ions, because of its hydrogen bond donor properties for solvating anions and its negatively polarised oxygen atom for solvating cations.