
Title	Pre-service teachers' conceptions of basic inorganic qualitative analysis
Author(s)	Kim-Chwee Daniel, Tan
Source	<i>Canadian Journal of Science, Mathematics and Technology Education</i> , 5(1), 7-20
Published by	Taylor & Francis (Routledge)

This document may be used for private study or research purpose only. This document or any part of it may not be duplicated and/or distributed without permission of the copyright owner.

The Singapore Copyright Act applies to the use of this document.

This is an Author's Accepted Manuscript of an Article published in Tan, K. C. D. (2005). *Canadian Journal of Science, Mathematics and Technology Education*, 5(1), 7-20, as published in the Canadian Journal of Science, Mathematics and Technology Education, 2005, © Taylor & Francis, available online at:
<http://www.tandfonline.com/10.1080/14926150509556641>

Notice: Changes introduced as a result of publishing processes such as copy-editing and formatting may not be reflected in this document. For a definitive version of this work, please refer to the published source.

Pre-Service Teachers' Conceptions of Basic Inorganic Qualitative Analysis

Kim-Chwee Daniel, Tan. *Nanyang Technological University, Singapore.*

ABSTRACT: Graduate teachers teaching secondary chemistry in Grades 9 and 10 in Singapore are required to prepare their students for a one-off practical examination which forms part of the General Certificate of Education Ordinary Level (O-level) chemistry examinations taken at the end of Grade 10. A qualitative analysis experiment is usually part of the practical examination. Previous research has shown that secondary students have difficulty in explaining the reactions and procedures involved in qualitative analysis (Tan et al., 2001, 2002), and a possible reason for this situation is that their teachers may also not have adequate understanding of the reactions and procedures involved, and hence, are unable to teach for understanding. A diagnostic test on O-level qualitative analysis was administered to a total 270 pre-service chemistry teachers from 1999 to 2003, and it was found that they had problems explaining the ion-exchange reactions that resulted in the formation of precipitates, and the use of dilute acid in tests for anions and when added to solutions containing complex salts such as zincates. The pre-service teachers also had difficulty explaining procedures and reactions involved when substances were heated. Thus, if the pre-service teachers have difficulty in understanding the reactions and procedures involved in qualitative analysis, it will not come as a surprise if their students also have similar difficulties with qualitative analysis.

INTRODUCTION

Qualitative analysis (QA) practical work requires students to carry out a series of procedures using reagents, apparatus and appropriate techniques to identify anions, cations and gases, and/or to deduce properties of unknown substances. The requirements of O-level QA are listed in Figure 1. For example, a Grade 10 student can be given a colourless solution and be required to determine the cation present in the solution. From the colour (or lack of colour) of the solution, the student can infer that ammonium, calcium, aluminium, or zinc ions may be present in solution. The student will then add aqueous sodium hydroxide to the unknown solution to determine whether a precipitate is formed, and if it is formed, its colour, and whether it reacts with excess aqueous sodium hydroxide can give clues to the identity of the unknown cation. If no precipitate is formed, the student has to gently heat the mixture and test for ammonia gas using a moist red litmus paper because ammonium ions, if present, will react with aqueous sodium hydroxide to liberate ammonia gas.

(Insert Figure 1 about here)

Tan et al. (2001, 2002) found that Grade 10 students had difficulty understanding the reactions and procedures involved in the identification of cations and anions, for example, the ion-exchange reactions resulting in the formation of precipitates, the formation and reaction of complex salts, and thermal decomposition. To make sense of the procedures, reactions and results in QA practical work, students need to apply content knowledge which they have learnt in topics such as 'Acids, Bases and Salts', 'Oxidation and Reduction', 'Reactivity of Metals' and 'Periodicity'. However, the Grade 10 students did not seem to see the links between what they had learnt in class and what they did in practical work, and without the theory to guide their experiments, it was likely that they would not know what to think about

and what to take note of in the experiments (Hart et al., 2000; Hodson, 1992; Tasker & Freyberg, 1985).

Another reason why students find QA difficult could be the content of QA. White (1994) described several properties of science content that influenced how the content should be taught and learned. These are openness to common experience, abstraction, complexity, presence of alternative models with explanatory power, presence of common words, mix of types of knowledge, demonstrable versus arbitrary, social acceptance, extent of links and emotive power. Students do not encounter QA in normal everyday life, only in the laboratory, so they have virtually no conception of it. The concepts behind the procedures in QA and the reactions that occur are abstract, complex and extensively linked to other concepts. For example, Fensham (1994) pointed out that students found what happened when substances were heated confusing because the substance could dehydrate, decompose, change its state, or undergo a combination of the processes! QA also involves a mix of knowledge and skills such as propositional and procedural knowledge, and manipulative and inferential skills. Thus, it is not surprising that students find QA very demanding and difficult.

Lenton and Turner (1999) found that science graduates did not necessarily understand or have sound knowledge of all parts of their own specialised subject, and that teaching or training in the subject area during a teacher-preparation course did not necessarily improve subject matter knowledge. "Teachers' knowledge about the subject matter and their conceptions about the phenomena they teach can enhance or limit students' learning" (Valanides, 2000, p. 250), so Lenton and Turner (1999) were concerned that the pre-service teachers might be "perpetuating the teaching of basic misconceptions in science" (p. 71). Indeed, studies have shown that pre-service teachers have alternative conceptions similar to that of students, for example, in the areas of chemical equilibrium (Quilez-Pardo & Solaz-Portoles, 1995), redox reactions (De Jong, Acampo, & Verdonk, 1995), and behaviour of

gases (Lin, Cheng, & Lawrenz, 2000). Teachers may unwittingly transmit their alternative conceptions to their students, and when they have the same alternative conceptions as their students, they think that there is nothing wrong with their students' conceptions (Wandersee, Mintzes, & Novak, 1994). Given the number of students taught over a teaching career, the generation of alternative conceptions can be quite significant (Valanides, 2000)

Thus, in addition to studying students' understanding of difficult science concepts, it is also important to determine teachers' understanding of the concepts. This is to enable teachers to be aware of their own difficulties and alternative conceptions, and how these problems may affect their teaching and their students' learning of the concepts. Lenton and Turner (1999) suggests that some form subject knowledge audit is necessary to gain an understanding of the alternative conceptions held by pre-service teachers so that guidance can be offered at an early stage of their program. They also propose that teacher preparation programs teach subject matter to the pre-service teachers, or have structured independent study if there is little time for face-to-face teaching.

PURPOSE

This study sought to determine the extent of graduate pre-service teachers' understanding and alternative conceptions of ion-exchange reactions resulting in the formation of precipitates, the formation and reaction of complex salts, and thermal decomposition reactions involved in O-level QA. A two-tier multiple choice diagnostic instrument, the Qualitative Analysis Diagnostic Instrument (QADI) (Tan et al., 2002) was used in the study. The items in the QADI are given in the Appendix.

METHOD AND PROCEDURES

The participants

The QADI was administered to 270 graduate pre-service teachers who enrolled in a chemistry pedagogy course from 1999 to 2003 in a teacher education institution in Singapore. One hundred and seventy-one of these graduate pre-service teachers were assigned chemistry as their first (major) teaching subject (C1) and 99 were assigned chemistry as their second (minor) teaching subject (C2). The graduate pre-service teachers are required to have two teaching subjects in their Postgraduate Diploma in Education course. The majority of the pre-service teachers taking chemistry as their first teaching subject had science degrees and majored in chemistry. The rest had material science, material engineering or chemical engineering degrees. Those who were assigned chemistry as a second teaching subject had at least Grade 12 chemistry if not a minor in chemistry at tertiary level. This group of teachers comprises mainly science graduates who majored in mathematics or biology. The content of the chemistry pedagogy course and the way the course was conducted were similar for both groups of pre-service teachers.

Administration and scoring of the QADI

The participants were told to read up on O-level QA a few days prior to the test. During the test, they were instructed to answer the items in the QADI without any discussion. A data sheet containing descriptions of the tests and test results for the anions, cations and gases specified in the syllabus (see Figure 1) was provided with the QADI for all participants to refer to. This same datasheet is supplied to Grade 10 students during their practical

examinations. There was no time restriction for the test, and on the average, the pre-service teachers took between 45 to 60 minutes to complete the QADI. If any pre-service teacher believed that the correct answer could not be found in the options provided, he/she could write it down at the back of the answer sheet – only 14 did so, each for one or two items. The participants' answer sheets were marked using an optical mark reader, and their results were analysed using SPSS version 11 (SPSS, 2002). Each item was considered to be correctly answered if a participant correctly responded to both parts of the item (Peterson & Treagust, 1989; Peterson, Treagust, & Garnett, 1989). In addition, seven trainee-teachers were interviewed (four were interviewed in pairs and the rest in a group of three) using the QADI as the interview protocol to determine if they had any difficulty in understanding the items and to probe the thinking behind their answers.

RESULTS

Some test statistics are given in Table 1. The results of Grade 10 students' performance on the QADI from a previous study (Tan et al., 2002) are also included as a comparison. The pre-service teachers did not fare very well on the QADI, with mean total scores less than 10 out of a possible 19. A one-way analysis of variance (ANOVA) showed that there was a significant difference between the three groups ($p=.000$). A post hoc pairwise multiple comparisons analysis (Tamhane) was conducted and it showed that there was no statistically significant difference between the two groups of pre-service teachers ($p=.414$). As expected, both groups of pre-service teachers' mean total scores were statistically significantly different than that of the Grade 10 students ($p=.000$ for both comparisons). However, any comparison needs to be taken with caution because of the

different numbers of Grade 10 students (n=915) and pre-service teachers (n[C1]=171, n[C2]=99) involved.

(Insert Table 1 about here)

Alternative conceptions

The alternative conceptions of the two groups of pre-service teachers and Grade 10 students of the ion-exchange reactions resulting in the formation of precipitates, the formation and reaction of complex salts, and thermal decomposition are given in Table 2. Alternative conceptions were considered significant if they existed in at least 10% of the student sample as a higher minimum value, say 25%, would possibly eliminate some valid alternative conceptions from the results (Tan et al., 2002). In general, the percentages of pre-service teachers in the two groups having the various alternative conceptions are similar but lower than that of the Grade 10 students. Many alternative conceptions still existed despite increased exposure of the pre-service teachers to chemical education.

(Insert Table 2 about here)

Displacement. The testing of anions and cations usually involves ion-exchange reactions resulting in the formation of precipitates (if any) – the colour of the precipitate and whether the precipitate reacts with excess reagent give clues to the identity of the unknown ion present. Butts and Smith (1987) found that students could not relate the formation of a precipitate in an ion-exchange reaction to the low solubility of the salt. This study was no different – many of the pre-service teachers and Grade 10 students believed that displacement

reactions took place in which more reactive ions displaced less reactive ones (items 1, 5, 13 and 18). For example, when aqueous sodium hydroxide was added to aqueous zinc chloride, 11% of the C1 group, 20% of the C2 group and 25% of the Grade 10 students believed that the 'more reactive' sodium ion displaces the 'less reactive' zinc ions (item 1, A3) in the reaction. Boo (1998) also found that students believed the driving force for ion-exchange reactions was the difference in reactivity between the metallic elements present in the compounds involved. Tan et al. (2002) believed that the participants' learning/memorisation of the reactivity series of metals interfered with their understanding of ion-exchange reaction. This could be seen by the two excerpts of interviews, one with Grade 10 students, and the other two with C1 pre-service teachers:

Question 1

S52: Because...sodium hydroxide will displace the...zinc chloride...cos...the zinc chloride is less stable than sodium chloride...so...a displacement reaction will happen.

I : Why did you think of a displacement reaction?

S53: We've got the reactivity series...then we learn the displacement...so we apply.

I : Why did you think of the reactivity series...is there any reason?

S53: We were made to memorise the reactivity series...so it comes naturally.

S52: The teacher always stresses the importance of the reactivity series, so the moment you see sodium...you see metals like sodium...any metal from the reactivity series, even though it is an ion, you think of reactivity series right away.

C1.4: Since...we're adding aqueous sodium hydroxide...I...ok...I chose number 3 right, my justification I said, sodium ion is more reactive than zinc ion.

I: Why did you choose 3?

C1.4: I cannot really remember the reactivity series but...sodium is very reactive...
right...so...it should...it is more reactive than zinc.

Question 5

I: Ok what is your reason?

C1.3: 1...the silver ions are displaced by the more reactive cations.

I: What do you choose 1?

C1.3: Again...once there is a white solid there has to be some displacement going
on ...and therefore the...whatever Q has, the reactive cations...if it is not
reactive then...I don't see it happening at all.

I: Interviewer

S52 and S53: Secondary (Grade 10) students.

C1.3 & C1.4: Pre-service teachers in the C1 group

Dissolution. A further step in the test for cations is to add excess alkali to any precipitate formed to determine if the precipitate reacts with the excess alkali to form a complex salt. For example, zinc hydroxide is amphoteric, and will react with excess aqueous sodium hydroxide to form a soluble zincate, while copper(II) hydroxide will react with excess aqueous ammonia to form a soluble ammine. However, in item 2, pre-service teachers (C1, 14%; C2, 15%), and to a greater extent, Grade 10 students (29%), believed that the precipitate merely dissolved in the excess alkali because there was more space/volume for it to dissolve in. Tan et al. (2002) argued that many students seemed to rely on perceptually-dominated thinking (Ebenezer & Erickson, 1996) – if a solid disappeared in a liquid, then it dissolved in the liquid or if no new substance was formed then no reaction had taken place.

Ribeiro, Pereira, and Maskill (1990) also reported that if students did not see a new substance being formed, they tended not to refer to the change as a reaction, while Novick and Nussbaum (1978) found that students thought mixtures were formed when no external means such as heating or electricity were used. This problem was further compounded by students being taught to write that the precipitate dissolved in excess reagent, a 'standard' answer required in the examinations to describe the disappearance of the precipitate. When several Grade 10 students were asked why they used the term 'dissolve', they either said that they were taught to do so, or that it was given in the data sheet that they used for QA practical work. Thus, formal instruction could have caused students to have the idea in the first instance that dissolution took place, and perceptually-dominated thinking provided the explanation. The pre-service teachers studied more advanced inorganic chemistry, and so did not have as much difficulty as the Grade 10 students with complex salt formation. It has to be noted that option A4 in item 2, a precipitate dissolved in a reagent because it formed a soluble compound with the reagent, was not considered as an alternative conception. Though the term 'dissolve' was inappropriately used in this situation, it could indicate that the participants understood what had occurred leading to the disappearance of the precipitate. In this case, understanding of the phenomenon was more important than the terms used to categorise the phenomenon (Brosnan, 1999).

One test for chloride is to add aqueous silver nitrate(V) to the unknown solution. If chloride is present, the silver chloride precipitate will be formed, and it will react with excess aqueous ammonia to form a soluble silver ammine – this is the reaction behind item 8. Many pre-service teachers (C1, 37%; C2, 46%) and Grade 10 students (41%) thought that ammonium chloride was formed in the reaction because it was a soluble salt. Secondary chemistry students have to memorise a list of common soluble and insoluble salts, and in that list, it is stated that all ammonium salts are soluble. Thus, the pre-service teachers'

knowledge of complex salt formation could have been pushed into the background by their stronger memories of soluble salts and their perception that the precipitate 'dissolved'. Two extracts of interviews with pre-service teachers are given below to illustrate this point:

C1.2: I choose A1...so I say that the ammonium chloride is soluble...that is why a colourless liquid is formed.

C1.6: I put it as true...it disappeared because it reacted...with it...the reason that I felt is true because...it disappeared because ammonium chloride is a soluble salt so that is why you cannot see anything.

Addition of acid. The pre-service teachers had difficulty explaining the tests for anions as shown by their responses for items 6, 11, and 17. For example, aqueous barium nitrate(V) and dilute nitric(V) acid are commonly used to test for sulfates(IV), sulfates(VI) and carbonates (item 11). Barium ions will combine with sulfate(IV), sulfate(VI) and carbonate ions to give the respective insoluble barium salt. On the addition of dilute nitric(V) acid, barium sulfate(IV) will liberate sulfur dioxide, barium carbonate will liberate carbon dioxide, while barium sulfate(VI) will remain unreacted. The common alternative conceptions determined were that aqueous barium nitrate(V) and dilute nitric(V) acid could be used only to test for sulfate(VI) (Q11, B3: C1, 11%, Grade 10, 20%), and that to test for a carbonate, the acid had to be added directly to the unknown sample (Q11, B4: C1, 15%; C2, 18%; Grade 10, 25%).

Further examples were given in items 6 (A5: C1, 12%; C2, 20%; Grade 10, 22%) and 17 (A4: C1, 22%; C2, 37%; Grade 10, 35%) where the pre-service teachers and Grade 10 students thought that dilute nitric(V) acid had to be added so that the unknown substances could react 'properly' with silver nitrate(V) and lead(II) nitrate(V), respectively. Many

Grade 10 and pre-service teachers could not explain the function of the dilute acid, as illustrated by the following comments:

I : Ok...what about question 6?

S58: I put acidify the mixture...basically I don't actually have a reason for it... basically because when we do practicals...we are told to acidify with nitric acid and they tell you that the purpose is to acidify...so I just take it at face value...that is to acidify the mixture and not for...I don't know like why you need to acidify it.

I: Have you wondered why you need to acidify?

S58: No because I accept things...the way they are...as in if you tell me I have to acidify if it is part of the procedure I need to do during practicals then I will just do it because I know I'm supposed to do it... and also because we are not questioned why either...so there is no desire to find out why since you are not questioned why.

I: What's the purpose of the acid?

C1.4: Acidify.

I: Ok...reason?

C1.4: I choose number 4 because there is no other choice which...I think...because like what I said...I never know...why...because we were not told...so I think ...acidification is necessary so that reaction can be carried out properly.

I: What do you mean by reaction can be carried out properly?

C1.4: May be we need hydrogen ions...in order for the mechanism to work...for the reaction mechanism to work.

Acidifying a mixture is a common procedure in QA practical work, but the reason why remains a mystery for many participants. The Grade 10 student and pre-service teacher in the above excerpts did not realize that the function of the acid was to react with sulfate(IV) or carbonate ions, if present, producing sulfur dioxide and carbon dioxide which could be identified by the appropriate tests. The students had learned the relevant reactions in the chapter on 'Acids, Bases and Salts' before they started on QA practical work, but they seemed unable to apply what they had learned to the QA practical work. Thus, they had little knowledge about what went on in their practical work (Hart et al., 2000; Hodson, 1992).

Heating. Pre-service teachers and Grade 10 students had difficulty explaining the role of heating in QA and/or the reactions that took place during heating. For example, in item 10 (A1), the pre-service teachers (C1, 15%, C2, 18%) and the Grade 10 students (23%) stated that all gases had to be tested when a substance was heated; they did not seem to realise that the only gases such as oxygen, carbon dioxide or sulphur dioxide could be liberated. The pre-service teachers (C1, 11%, C2, 16%) and Grade 10 students (26%) who chose B1 in item 19 believed that all ionic compounds do not decompose on heating as illustrated by the following excerpt of an interview.

C1.1: I put...B1...because it is ionic compound...you already know it is an ionic compound...and normally...ionic compounds have very strong bonds...so you don't test for gases in this way...I mean ionic compounds have strong bonds and do not decompose...or do not easily decompose by heating...that's what I think.

The pre-service teachers and Grade 10 students seemed to have forgotten their experiences with the compounds (for example, carbonates and nitrates(V)) that they heated during their practical work.

In item 10 (B3), the pre-service teachers (C1, 35%, C2, 32%) and Grade 10 students (27%) thought that oxygen could not be liberated when a substance was heated because it was used up during heating. Perhaps they were thinking more about combustion, which was more common in everyday life, rather than thermal decomposition. The pre-service teachers and Grade 10 students would have heated nitrate(V) salts several times in QA practical work, and would have obtained positive results for oxygen. They might have treated each experiment as isolated events (Tasker & Freyberg, 1985), and were unable to link and apply what they had learnt. Fensham (1994) found that students had difficulty understanding the reactions that could occur during the heating of substances, and there might be a need for further studies on students' conceptions of thermal decomposition as most studies on the heating of substances focussed on students' conceptions of oxidation/combustion (e.g., Boo, 1998; BouJaoude, 1991; Watson, Prieto, & Dillon, 1997).

DISCUSSION

In summary, many of the pre-service teachers had similar alternative conceptions as Grade 10 students, and this indicated that the alternative conceptions were "robust enough to have survived schooling" (Palmer, 1999, p. 648). When interviewed, many Grade 10 students admitted that they had little idea about what they were doing during QA practical sessions (Tan et al., 2001). They often did not know why they were instructed to use a certain reagent, what they were testing for, what reactions occurred, or why they obtained a particular result. They focused mainly on correct observations and identification of the

unknown substances (with the help of the datasheet provided) as these accounted for the bulk of the marks in QA practical examinations. Two pre-service teachers commented that they also focussed on results, even when they did QA practical work in the university as their practical work was also graded on their ability to identify the unknown ions rather than their understanding of the procedures and reactions involved.

C1.4: Personally for me...from day one when I did QA till...in the university right...it's all about results...you were never asked why...so it's like you have to produce results...it's like you're given a list...so if you check and find that this...result corresponds to this compound...and ...you never stop to ask yourself why because you don't have the time...you really have to do it...and the lecturers never ask you why...you just concentrate on getting the results.

C1.3: Yah...same here...the teachers never emphasize why.

C1.4: You just concentrate on the results.

I: So you feel this affects the learning of QA.

C1.4: It affects...because you just blindly follow the list and you know that oh...I get yellow so I go to the QA list and see which one is yellow...but I don't really know what is happening.

Should QA be part of the chemistry curriculum for Grades 9 and 10? As mentioned in the introduction, the reactions involved in QA are taught in the topics, 'Acids, Bases and Salts', 'Oxidation and Reduction', 'Reactivity of Metals' and 'Periodicity', so the theory involved in QA is not beyond the level of the students. However, students do not seem to be able to relate what they have learnt in class to what they do in practical work, so teachers need to make these links explicit to the students. The Qualitative Analysis Teaching Package

(QATP) (Tan et al., in press) was developed to help students make these links. One of the aims of the QATP is to allow students to gain tacit knowledge (Woolnough & Allsop, 1985) of the phenomena, reagents and apparatus involved in QA, and to construct explanations of the phenomena they observed. For example, students will be instructed to add aqueous sodium hydroxide to aqueous iron(II) chloride and observe the formation of the green precipitate of iron(II) hydroxide. They will then view computer animation which illustrates the ion-exchange reaction involved to get a sense of what happens at the microscopic level (Garnett et al., 1995; Russell et al., 1997; Wu, Krajcik, & Soloway, 2001) during the formation of the precipitate. Following this, the students will be asked to explain how the iron(II) hydroxide precipitate is formed and to write equations (chemical and ionic) to describe the reaction. Thus, students learn the reaction at the macroscopic, microscopic and symbolic levels (Nakhleh & Krajcik, 1994). Teachers will remind the students that they first encountered this reaction in the chapter on 'Acids, bases, and Salts', and also point out that similar reactions occur in the tests for other cations and anions so that the students will understand that these tests are based on the same reaction – the exchange of ions leading to the formation of an insoluble substance. In addition to the content knowledge required for QA, the QATP also emphasizes the development of the process skills required to carry out the procedures in QA practical work, as well as the approach or thinking required when doing QA experiments. Since 2001, pre-service teachers were introduced to the QATP during sessions on practical work in their methods module, and the QATP has also been made available online for them to use in school.

Two two-tier multiple choice diagnostic tests, the QADI and one on chemical bonding (Tan & Treagust, 1999), were also administered, since 2001, to every intake of pre-service chemistry teachers in the author's institution. After the tests, the pre-service teachers were assigned a number of questions to discuss in small groups and to present their answers to the

rest of the class. The feedback received was that these sessions were valuable to the pre-service teachers as they clarified many things that the pre-service teachers took for granted, or were not aware of, in chemical bonding and QA. This highlighted the need to include sessions of chemistry content knowledge, for example, discussion of concepts which secondary students have difficulty understanding (Garnett, Garnett, & Hackling, 1995; Nakhleh, 1992) in the preparation of chemistry teachers in Singapore. However, the pre-service teachers first have to be motivated to examine their understanding of basic chemistry concepts – many pre-service teachers were 'shaken' after the tests, and this made them very receptive to such examination during their methods as well as assessment modules. The use of diagnostic instruments and the discussion of items that follows can be a way of auditing pre-service teachers' chemistry content knowledge and incorporating curriculum content knowledge in a teacher preparation program, as suggested by Lenton and Turner (1999).

CONCLUSIONS

This study showed that, in general, a significant number of pre-service teachers did not have adequate understanding of basic secondary QA. The prevalence of alternative conceptions among the pre-service teachers showed that there were common conceptions among the pre-service teachers and the Grade 10 students, and that the alternative conceptions were retained even with additional years of chemical education (Abraham, Williamson, & Westbrook, 1994; Birk & Kurtz, 1999; Palmer, 1999; Watson et al., 1997). Many of the pre-service teachers still had little understanding of the procedures and reactions involved in QA, or were unable to apply their additional knowledge of inorganic chemistry. Thus, if the pre-service teachers have difficulty in understanding the reactions and procedures involved in QA, it will not come as a surprise if their students also have similar difficulties

with QA. The way QA is taught in secondary schools needs to be improved, and the use of the QATP may be a way to do so. It may also be necessary to audit the curriculum content knowledge of pre-service teachers and to include curriculum content knowledge as part of a teacher preparation program to improve the teaching of the chemistry in school.

REFERENCES

- Abraham, M.R., Williamson, V.M., & Westbrook, S.L. (1994). A cross-age study of the understanding of five chemistry concepts. *Journal of Research in Science Teaching*, 31(2), 147-165.
- Boo, H.K. (1998). Students' understanding of chemical bonds and the energetics of chemical reactions. *Journal of Research in Science Teaching*, 35(5), 569-581.
- BouJaoude, S.B. (1991). A study of the nature of students' understanding about the concept of burning. *Journal of Research in Science Teaching*, 28(8), 689-704.
- Birk, J.P. & Kurtz, M.J. (1999). Effect of experience on retention and elimination of misconceptions about molecular structure and bonding. *Journal of Chemical Education*, 76(1), 124-128.
- Brosnan, T. (1999). When is a chemical change not a chemical change? *Education in Chemistry*, 36(2), 56.
- Butts, B. & Smith, R. (1987). HSC chemistry students' understanding of the structure and properties of molecular and ionic compounds. *Research in Science Education*, 17, 192-201.
- De Jong, O., Acampo, J., & Verdonk, A. (1995). Problems in teaching the topic of redox reaction: Actions and conceptions of chemistry teachers. *Journal of Research in Science Teaching*, 32(10), 1097-1110.

- Ebenezer, J.V. & Erickson, G.L. (1996). Chemistry students' conceptions of solubility: A phenomenography. *Science Education*, 85(5), 509-535.
- Fensham, P.J. (1994). Beginning to teach chemistry. In Fensham, P.J., Gunstone, R.F. & White, R.T. (Eds.), *The content of science: A constructivist approach to its teaching and learning* (pp. 14-28). London: Falmer Press.
- Garnett, P.J., Garnett, P.J., & Hackling, M.W. (1995). Students' alternative conceptions in chemistry: A review of research and implications for teaching and learning. *Studies in Science Education*, 25, 69-95.
- Hart, C., Mulhall, P., Berry, A., Loughran, J., & Gunstone, R. (2000). What is the purpose of this experiment? Or can students learn something from doing experiments? *Journal of Research in Science Teaching*, 37(7), 655-675.
- Hodson, D. (1992). Redefining and reorienting practical work in school science. *School Science Review*, 73(264), 65-78.
- Lenton, G. & Turner, L. (1999). Student-teachers' grasp of science concepts. *School Science Review*, 81(295), 67-72.
- Lin, H.S., Cheng, H.J., & Lawrenz, F. (2000). The assessment of students' and teachers' understanding of gas laws. *Journal of Chemical Education*, 77(2), 235-237.
- Nakhleh, M.B. (1992). Why some students don't learn chemistry: chemical misconceptions. *Journal of Chemical Education*, 69(3), 191-196.
- Nakhleh, M.B. & Krajcik, J.S. (1994). Influence of levels of information as presented by different technologies on students' understanding of acid, base and pH concepts. *Journal of Research in Science Teaching*, 31(10), 1077-1096.
- Novick, S. & Nussbaum, J. (1978). Junior high school pupils' understanding of the particulate nature of matter: an interview study. *Science Education*, 62(3), 273-281.

- Palmer, D.H. (1999). Exploring the link between students' scientific and nonscientific conceptions. *Science Education*, 83(6), 639-653.
- Peterson, R.F. & Treagust, D.F. (1989). Grade-12 students' misconceptions of covalent bonding and structure. *Journal of Chemical Education*, 66(6), 459-460.
- Peterson, R.F., Treagust, D.F. & Garnett, P. (1989). Development and application of a diagnostic instrument to evaluate grade-11 and -12 students' concepts of covalent bonding and structure following a course of instruction. *Journal of Research in Science Teaching*, 26(4), 301-314.
- Quilez-Pardo, J. & Solaz-Portoles, J.J. (1995). Students' and teachers' misapplication of Le Chatelier's principle: Implications for the teaching of chemical equilibrium. *Journal of Research in Science Teaching*, 32(9), 939-957.
- Ribeiro M.G.T.C., Pereira, D.J.V.C., & Maskill, R. (1990). Reaction and spontaneity: the influence of meaning from everyday language on fourth year undergraduates' interpretations of some simple chemical phenomena. *International Journal of Science Education*, 12(4), 391-401.
- Russel, J.W., Kozma, R.B., Jones, T., Wykoff, J., Marx, N., & Davis, J. (1997). Use of simultaneous-synchronized macroscopic, microscopic, and symbolic representations to enhance the teaching and learning of chemical concepts. *Journal of Chemical Education*, 74(3), 330-334.
- SPSS (2002). *SPSS for Windows* (Release 11.5.1) [Computer Software]. Chicago: SPSS Inc.
- Tan, K.C.D., Goh, N.K., Chia, L.S., & Treagust, D.F. (2001). Secondary students' perceptions about learning qualitative analysis in inorganic chemistry. *Research in Science & Technological Education*, 19(2), 223-234.
- Tan, K.C.D., Goh, N.K., Chia, L.S., & Treagust, D.F. (2002). Development and application of a two-tier multiple choice diagnostic instrument to assess high school students'

- understanding of inorganic chemistry qualitative analysis. *Journal of Research in Science Teaching*, 39(4), 283-301.
- Tan, K.C.D., Goh, N.K., Chia, L.S., & Treagust, D.F. (in press). Qualitative analysis practical work. *School Science Review*.
- Tan, K.C.D. & Treagust, D.F. (1999). Evaluating students' understanding of chemical bonding. *School Science Review*, 81(294), 75-83.
- Tasker, R. & Freyberg, P. (1985). Facing the mismatches in the classroom. . In Osborne, R & Freyberg, P. (Eds.), *Learning in science: The implications of children's science*. (pp. 66-80). Auckland, London: Heinemann.
- Valanides, N. (2000). Primary student teachers' understanding of the particulate nature of matter and its transformation during dissolving. *Chemistry Education: Research and Practice in Europe*, 1(2), 249-262 [Available at [http://www.uoi.gr/cerp/](http://www.uoi.gr/ceerp/)]
- Wandersee, J.H., Mintzes, J.J., & Novak, J.D. (1994). Research on alternative conceptions in science. In Gabel, D.L. (Ed.), *Handbook of research on science teaching and learning* (pp. 177-210). New York: Macmillan.
- Watson, R., Prieto, T., & Dillon, J.S. (1997). Consistency of students' explanations about combustion. *Science Education*, 81(4), 425-444.
- White, R.T. (1994). Dimensions of content. In Fensham, P.J., Gunstone, R.F. & White, R.T. (Eds.), *The content of science: A constructivist approach to its teaching and learning*. (pp. 225-262). London: Falmer Press.
- Woolnough, B. & Allsop, T. (1985). *Practical work in science*. Cambridge: Cambridge University Press.
- Wu, H.-K., Krajcik, J.S., & Soloway E. (2001). Promoting understanding of chemical representations: Students' use of a visualization tool in the classroom. *Journal of Research in Science Teaching*, 38(7), 821-842.

Figure 1. *Sections on redox and the identification of ions and gases in the O-level syllabus.*

7.3 Redox

- d. Describe the use of aqueous potassium iodide, acidified potassium dichromate (VI) and acidified potassium manganate (VII) in testing for oxidising and reducing agents from the colour changes produced.

8.4 Identification of ions and gases

Candidates should be able to describe and explain the use of the following tests to identify:

a. Aqueous cations

Aluminium, ammonium, calcium, copper(II), iron(II), iron (III) and zinc, using aqueous sodium hydroxide and aqueous ammonia, as appropriate. (Formula of complex ions are not required.)

b. Anions

Carbonates (by reactions with dilute acid and then limewater), chloride (by reaction, under acidic conditions, with aqueous silver nitrate), iodide (by reaction, under acidic conditions, with aqueous lead (II) nitrate), nitrate (by reduction with aluminium to ammonia) and sulfate (by reaction, under acidic conditions, with aqueous barium ions).

c. Gases

Ammonia (using damp red litmus paper), carbon dioxide (using limewater), chlorine (using damp litmus paper), hydrogen (using lighted splint), oxygen (using glowing splint) and sulfur dioxide (using acidified potassium dichromate (VI))

Table 1. *Test statistics for the administration of the QADI to pre-service teachers and Grade 10 students*

	C1	C2	Grade 10
No. of cases	171	99	915
No. of items	19	19	19
Cronbach alpha reliability	.84	.79	.68
Mean (Standard deviation)	9.91 (4.69)	9.14 (4.16)	5.76 (3.28)
Median / Mode	10.00 / 12	9.00 / 8	5.00 / 5
Minimum / Maximum	1 / 19	1 / 19	0 / 18

Notes:

C1 represents pre-service teachers with chemistry as their first teaching subject

C2 represents pre-service teachers with chemistry as their second teaching subject

Table 2. *Alternative conceptions of the pre-service teachers and the Grade 10 students*

Alternative conception	Choice combination	Percentage of students with the alternative conception		
		Chem 1	Chem 2	Grade 10
<i>Displacement</i>				
1. A more reactive ion displaces a less reactive ion in an ion-exchange reaction.	Q1 (A3)	11	20	25
	Q5 (A1,A4)	28	25	37
	Q13 (A3,A4)	~	10	15
	Q18 (A1,A2, A4&A5)	14	21	29
2. A more reactive ion displaces a less reactive ion in complex salt formation.	Q8 (A3)	12	~	15
<i>Dissolution</i>				
1. On further addition of excess reagent, the precipitate disappears because more excess reagent means more space/volume for the precipitate to dissolve.	Q2 (A1)	14	15	29
	Q14 (A2)	15	15	25
2. Ammonium chloride is formed when aqueous ammonia is added to silver chloride because it is a soluble salt.	Q8 (A1)	37	46	41

<i>Addition of acid</i>				
1. Acid is need to acidify the mixture	Q6 (A5)	12	20	22
so that reaction can proceed properly.	Q17 (A4)	22	37	35
2. Dilute nitric(V) acid is added to	Q7 (A3)	13	~	~
acidify the mixtures because it is a strong oxidising agent.	Q12 (A1)	12	16	~
3. Carbonate ions cannot be identified if acid is added after the addition of barium nitrate(V)				
a. The acid must be added directly to the unknown.	Q11 (B4)	15	18	25
	Q12 (B4)	16	16	20
b. The procedure is strictly a test for sulfate(VI).	Q11 (B3)	11	~	20
c. Insoluble carbonates will not react with acid.	Q11 (B1)	12	10	~
<i>Heating</i>				
1. All gases have to be tested when a substance is heated.	Q10 (A1)	15	18	23
2. Oxygen cannot be produced when a substance is heated because it is used up during heating.	Q10 (B3)	35	32	27
3. Ionic compounds have strong bonds and do not decompose on heating.	Q19 (B1)	11	16	26

Note: ~ represents a figure which is less than 10%

Appendix: *The Qualitative Analysis Diagnostic Instrument (QADI)*

For Questions 1 to 4, refer to Experiment A:

Experiment A

Step	Test	Observations
a	To a sample of aqueous zinc chloride, add aqueous sodium hydroxide until a change is seen.	<i>A white solid is obtained.</i>
b	Add excess of aqueous sodium hydroxide to the mixture from (a).	<i>White solid disappears in excess reagent to give a colourless solution.</i>
c	Add dilute nitric (V) acid (HNO_3) to the mixture from (b) until no further change is seen.	<i>White solid reappears. When excess acid is added, the solid disappears giving a colourless solution.</i>

1. What happens when aqueous sodium hydroxide is added to aqueous zinc chloride resulting in the white solid?

A Displacement

B Precipitation

C Redox

Reason/Justification

- (1) The solution is too concentrated with sodium chloride so the sodium chloride comes out of the solution as a solid.
- (2) Sodium hydroxide loses oxygen in forming sodium chloride and zinc chloride gains oxygen in forming zinc hydroxide.
- (3) Sodium ion is more reactive than zinc ion.
- (4) Zinc ions combine with the hydroxide ions.

2. In step (b), a colourless solution is obtained because the white solid _____ the excess sodium hydroxide.

A dissolves in

B reacts with

Reason/Justification

- (1) More solvent is added so there is more space for the white solid to dissolve.
- (2) No further reaction is seen except for the disappearance of the white solid, and no new reagent is added.
- (3) Sodium ion displaces the cation from the white solid.
- (4) The white solid forms a new soluble compound with the excess sodium hydroxide.

3. A student concludes that the white solid obtained in step (c) is the same as the white solid obtained in step (a). Do you agree with the student's conclusion?

A Yes B No

Reason/Justification

- (1) Different reagents were used.
 - (2) The acid reacts with the excess sodium hydroxide to form sodium nitrate (V) which appears as the white solid.
 - (3) The acid reacts with the zinc compound to form zinc nitrate (V) which appears as the white solid.
 - (4) The acid reacts with the mixture to reverse the formation of the soluble compound in step (b).
 - (5) The acid removes the solvent which dissolves the white solid in step (b), so the white solid reappears.
4. The student also concludes that, in step (c), the white solid dissolves because more solvent (dilute nitric (V) acid) is added. Do you agree with the student's conclusion?

A Yes B No

Reason/Justification

- (1) Adding more acid dilutes the solution.
- (2) Hydrogen is more reactive than the cation in the white solid, so it displaces the cation from the solid.
- (3) No further reaction is seen except for the disappearance of the white solid, and no new reagent is added.
- (4) The acid contains hydrogen ions which reduce the white solid.
- (5) The acid reacts with the white solid to form a new soluble compound.

For Questions 5 to 9, refer to Experiment B:

Experiment B

Step	Test	Observations
	Q is an aqueous solution of a compound which containing a cation and an anion which could possibly be chloride.	
a	To a portion of Q, add an equal volume of aqueous silver nitrate (V) (AgNO_3). Divide the mixture into 2 portions.	<i>A white solid is obtained.</i>
b	To the first portion, add dilute nitric (V) acid.	<i>No visible reaction. The white solid remains.</i>
c(i)	To the second portion, add aqueous ammonia.	<i>White solid disappears and a colourless liquid is formed.</i>
c(ii)	To the mixture from c(i), add dilute nitric (V) acid until a change is seen.	<i>White solid appears.</i>

5. What is the white solid obtained in step (a)?

- A AgCl
- B ZnCl_2
- C $\text{Zn}(\text{NO}_3)_2$

Reason/Justification

- (1) The silver ions are displaced by the more reactive cations from Q.
- (2) The silver ions combine with the chloride ions.
- (3) The white solid disappears when aqueous ammonia is added in step c(i).
- (4) The nitrate (V) ions are displaced by the more reactive chloride ions.

6. In step (b), the purpose of adding the dilute nitric (V) acid is to:

- A acidify the mixture.
- B determine if the sample contains carbonate ions.
- C dissolve the white solid.

Reason/Justification

- (1) All nitrate (V) salts are soluble.
- (2) Carbonate ions form a white solid with silver nitrate (V) which will react with nitric (V) acid.
- (3) Dilute nitric (V) acid is a strong oxidising agent.
- (4) Dilute nitric (V) acid is a good solvent.
- (5) So that Q can react properly with silver nitrate (V).

7. In step (b), can dilute hydrochloric acid be added instead of dilute nitric (V) acid?

A Yes

B No

Reason/Justification

- (1) Both nitrate (V) and chloride ions are already present in the mixture.
- (2) Chloride ions from dilute hydrochloric acid will interfere with the test.
- (3) Dilute hydrochloric acid can be used as it has similar properties and reactions as dilute nitric (V) acid.
- (4) Dilute hydrochloric acid will not react with the white solid.
- (5) Dilute hydrochloric acid will react with the white solid.

8. In step (c (i)), it can be concluded that the white solid disappeared because it reacted with the aqueous ammonia to form ammonium chloride.

A True

B False

Reason/Justification

- (1) Ammonium chloride is a soluble salt.
- (2) Chloride ions still present in solution react with the aqueous ammonia.
- (3) The ammonium ion is more reactive than the silver ion, so it displaces the silver ion.
- (4) The aqueous ammonia reacts with the white solid to produce a soluble compound which is not ammonium chloride.

9. In step (c (ii)), the hydrogen ions in the acid reduce the silver ions present to form the white solid.

A True B False

Reason/Justification

- (1) The acid decomposes the ammonium chloride to liberate chloride ions which react with the silver ions present in solution.
 - (2) The acid reacts with the aqueous ammonia to produce a new insoluble salt.
 - (3) The acid reacts with the aqueous ammonia and the soluble compound in step (c(i)) to produce the same white solid as in step (a).
 - (4) The acid removes the ammonium ions so that silver ions can react with hydroxide ions.
 - (5) The white solid is the element, silver.
10. Will you test for oxygen gas when you heat an unknown solid?

A Yes B No

Reason/Justification

- (1) All gases must be tested when a substance is heated.
- (2) Oxygen gas is produced only when acids react with compounds containing oxygen.
- (3) Oxygen gas will not be liberated during heating, instead it would be used up.
- (4) Some compounds decompose on heating to give oxygen gas.

11. A student is given a solution which may contain a carbonate ion. She decides to add aqueous barium nitrate (V) ($\text{Ba}(\text{NO}_3)_2$) to the solution first, followed by dilute nitric (V) acid. Is it possible for her to determine whether a carbonate ion is present when she carries out the above procedure?

A Yes

	B	No
1	0.0000	0.0000
2	0.0000	0.0000
3	0.0000	0.0000
4	0.0000	0.0000
5	0.0000	0.0000
6	0.0000	0.0000
7	0.0000	0.0000
8	0.0000	0.0000
9	0.0000	0.0000
10	0.0000	0.0000
11	0.0000	0.0000
12	0.0000	0.0000
13	0.0000	0.0000
14	0.0000	0.0000
15	0.0000	0.0000
16	0.0000	0.0000
17	0.0000	0.0000
18	0.0000	0.0000
19	0.0000	0.0000
20	0.0000	0.0000
21	0.0000	0.0000
22	0.0000	0.0000
23	0.0000	0.0000
24	0.0000	0.0000
25	0.0000	0.0000
26	0.0000	0.0000
27	0.0000	0.0000
28	0.0000	0.0000
29	0.0000	0.0000
30	0.0000	0.0000
31	0.0000	0.0000
32	0.0000	0.0000
33	0.0000	0.0000
34	0.0000	0.0000
35	0.0000	0.0000
36	0.0000	0.0000
37	0.0000	0.0000
38	0.0000	0.0000
39	0.0000	0.0000
40	0.0000	0.0000
41	0.0000	0.0000
42	0.0000	0.0000
43	0.0000	0.0000
44	0.0000	0.0000
45	0.0000	0.0000
46	0.0000	0.0000
47	0.0000	0.0000
48	0.0000	0.0000
49	0.0000	0.0000
50	0.0000	0.0000
51	0.0000	0.0000
52	0.0000	0.0000
53	0.0000	0.0000
54	0.0000	0.0000
55	0.0000	0.0000
56	0.0000	0.0000
57	0.0000	0.0000
58	0.0000	0.0000
59	0.0000	0.0000
60	0.0000	0.0000
61	0.0000	0.0000
62	0.0000	0.0000
63	0.0000	0.0000
64	0.0000	0.0000
65	0.0000	0.0000
66	0.0000	0.0000
67	0.0000	0.0000
68	0.0000	0.0000
69	0.0000	0.0000
70	0.0000	0.0000
71	0.0000	0.0000
72	0.0000	0.0000
73	0.0000	0.0000
74	0.0000	0.0000
75	0.0000	0.0000
76	0.0000	0.0000
77	0.0000	0.0000
78	0.0000	0.0000
79	0.0000	0.0000
80	0.0000	0.0000
81	0.0000	0.0000
82	0.0000	0.0000
83	0.0000	0.0000
84	0.0000	0.0000
85	0.0000	0.0000
86	0.0000	0.0000
87	0.0000	0.0000
88	0.0000	0.0000
89	0.0000	0.0000
90	0.0000	0.0000
91	0.0000	0.0000
92	0.0000	0.0000
93	0.0000	0.0000
94	0.0000	0.0000
95	0.0000	0.0000
96	0.0000	0.0000
97	0.0000	0.0000
98	0.0000	0.0000
99	0.0000	0.0000
100	0.0000	0.0000

Reason/Justification

- (1) An insoluble carbonate would be formed leaving no free carbonate ions in solution to react with the acid.
- (2) Dilute nitric (V) acid will react with both a soluble and an insoluble carbonate.
- (3) The above procedure is strictly to test for the presence of sulfate (VI) only.
- (4) The acid must be added directly to the solution to test for the presence of a carbonate.
- (5) The unknown compound will only react with the dilute nitric (V) acid and not with the barium nitrate (V).

12. Instead of dilute nitric (V) acid, can the student add dilute sulfuric (VI) acid (H_2SO_4) after the addition of barium nitrate (V) in Question 11?

A Yes

B No

Reason/Justification

- (1) Any acid can be used as they have similar properties and reactions.
- (2) Sulfate (VI) ions from dilute sulfuric (VI) acid will interfere with the test.
- (3) Dilute sulfuric (VI) acid will react with the nitrate (V) ions.
- (4) The addition of barium nitrate (V) has already invalidated (spoilt) the test for carbonates.

For Questions 13 to 16, refer to Experiment C:

Experiment C

Step	Test	Observations
a	To a sample of aqueous copper (II) sulfate (VI), add aqueous ammonia until a change is seen.	<i>A light blue solid is obtained.</i>
b	Add excess of aqueous ammonia to the mixture from (a).	<i>Light blue solid disappears in excess aqueous ammonia to give a deep blue solution.</i>
c	Add dilute sulfuric (VI) acid to the mixture from (b) until no further change is seen.	<i>A light blue solid appears. When excess acid is added, the solid disappears giving a light blue solution.</i>

13. What happens when aqueous ammonia is added to aqueous copper (II) sulfate (VI) in step (a)?

- A Displacement
- B Precipitation
- C Redox

Reason/Justification

- (1) Aqueous ammonia gains oxygen in forming ammonium sulfate (VI) but copper (II) sulfate (VI) loses oxygen in forming copper (II) hydroxide.
- (2) Copper (II) ions combine with the hydroxide ions.
- (3) Copper (II) ion is more reactive than ammonium ion.
- (4) Copper (II) ion is less reactive than the ammonium ion.

14. In step (b), why does the light blue solid disappear?

- A It dissolves in aqueous ammonia.
- B It reacts with aqueous ammonia.

Reason/Justification

- (1) Ammonium ion displaces the cation from the light blue solid.
- (2) More solvent is added so there is more volume for the light blue solid to dissolve in.
- (3) No further reaction is seen except for the disappearance of the light blue solid, and no new reagent is added.
- (4) There is a chemical reaction between the light blue solid and excess ammonia forming product(s) which is/are soluble.

15. The light blue solid obtained in step (a) and in step (c) is the same.

A True

B False

Reason/Justification

- (1) Different reagents were used.
- (2) The acid reacts with the copper (II) compound to form copper (II) sulfate (VI) which appears as the light blue solid.
- (3) The acid reacts with the mixture to reverse the formation of the soluble compound in step (b).
- (4) The acid removes the solvent which dissolves the light blue solid in step (b), so the light blue solid reappears.

16. Excess dilute sulfuric (VI) acid acts as a solvent for the light blue solid in step (c).

A True

B False

Reason/Justification

- (1) Adding more acid dilutes the mixture.
- (2) Hydrogen is more reactive than the cation in the light blue solid, so it displaces the cation from the solid.
- (3) No further reaction is seen except for the disappearance of the light blue solid, and no new reagent is added.
- (4) The acid contains hydrogen ions which reduce the light blue solid.
- (5) The acid reacts with the light blue solid to form a new soluble compound.

For Questions 17 to 18, refer to Experiment D:

Experiment D

Step	Test	Observations
	R is a colourless aqueous solution of a compound containing a cation and an anion which could possibly be iodide.	
a	To a portion of R, add an equal volume of dilute nitric (V) acid.	<i>No visible reaction, a colourless solution remains.</i>
b	To the mixture from (a), add a small volume of aqueous lead (II) nitrate (V) ($\text{Pb}(\text{NO}_3)_2$).	<i>Yellow solid is obtained.</i>

17. The purpose of adding the dilute nitric (V) acid in step (a) is to

- A acidify the mixture.
- B determine if R reacts with the acid.

Reason/Justification

- (1) All nitrate (V) salts are soluble.
- (2) Dilute nitric (V) acid is a strong oxidising agent.
- (3) Dilute nitric (V) acid is a good solvent.
- (4) So that R can react properly with lead (II) nitrate (V).
- (5) The acid will react with any carbonate ion if they are present in R.

18. How is the yellow solid formed?

- A Displacement
- B Precipitation

Reason/Justification

- (1) The lead (II) ion is more reactive than the cation from R.
- (2) The lead (II) ion is less reactive than the cation from R.
- (3) The lead (II) ions combine with iodide ions.
- (4) The iodide ions are more reactive than the nitrate (V) ions.
- (5) The iodide ions are less reactive than the nitrate (V) ions.

19. A student believes that she has to test for hydrogen and carbon dioxide when she heats an unknown ionic compound (in powder form). Do you agree?

A Yes B No

Reason/Justification

- (1) Ionic compounds have strong bonds and do not decompose on heating.
- (2) Gases are only evolved when covalent compounds are heated.
- (3) Some carbonates decompose on heating to give carbon dioxide but hydrogen is never liberated when any ionic compound is heated.
- (4) The ionic compound would react with oxygen on heating to give water and/or carbon dioxide.
- (5) Those ionic compounds containing carbonate, hydrogen or hydroxide ions will liberate carbon dioxide or hydrogen on heating.

Note: Items 6, 11 and 17 will give sulfur dioxide if sulfate(IV) is present. However, it is not included in this version of the QADI because sulfate(IV) is not included in the Singapore Grade 10 chemistry syllabus. A more general version of the QADI is available from the author.