






General Chemistry Collection

InQual-S

Windows-compatible computers

User's Guide (Teacher's Edition)

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Flowcharts

Flochar.pdf

 The pages in these sections sections may be reproduced for use in the classroom.

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Abstract

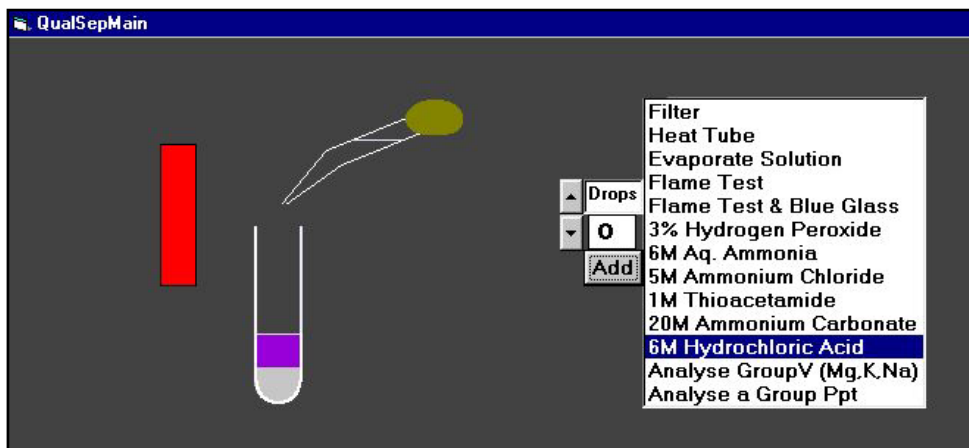
InQual-S is a simulation of inorganic qualitative analysis using the insolubility of sulfides as the main avenue to separation. This simulation allows for the identification of eighteen common cations in a mixture of their nitrates. The separation and testing methods used by this software allow the user to approximate those of Hogness, Johnson, and Armstrong (1) and to a lesser extent, those of King (2).

InQual-S allows students to start with a solution of known identity with 1–18 cations or with a sample containing from 1–10 cations that are randomly selected by the computer and not known to the user. The cations are divided into groups depending upon whether they give insoluble chlorides, acid insoluble sulfides, base insoluble sulfides, insoluble carbonates, and none of the previous classes. Each group is then subjected to a variety of reagents to individually identify each cation.

If the suggested scheme is followed, InQual-S reproduces the expected behavior of these cations and results in the successful identification of each cation present in the original mixture. However, InQual-S allows the user to add any of the reagents supplied in any order and in any amount. So, just as in the real laboratory, a wrong reagent at the wrong time in the wrong amount can lead to results that can be very difficult to interpret.

In addition to the 29 reagents that can be added, the user can filter, heat, evaporate and run flame tests (with or without cobalt glass) on the sample. During the simulation, volatile reagents will be lost on heating, carbonates will bubble on contact with acid, and precipitates will separate and redissolve.

With 18 cations and 29 reagents, the number of possible variations of solution and precipitates is very high. While the author has attempted to anticipate all possible reactions, it is almost certain that some have been overlooked and others misrepresented. Nevertheless, the program will mimic all the common behaviors of these combinations of cations and anions as the acidity and ammonium ion concentration of the solutions change.



This screen from InQual-S shows what happens when hydrochloric acid is added to a mixture of cations to be separated and identified. The strip at left is pH paper indicating the approximate pH of the contents of the test tube. The list at right gives choices for the next step.

InQual-S is intended for use by high school or first year college students of chemistry. Those users will see the colors of the commonly precipitated solids of inorganic chemistry and the solubility rules that govern their precipitation, and should develop skills in interpreting the behavior of cations under a variety of reaction conditions.

Hardware and Software Requirements

Hardware and software requirements for InQual-S are listed in Table 1.

Table 1. Hardware and software required.

Computer	CPU	RAM	Graphics	Operating System
Windows Compatible	80486 or higher, Pentium suggested	16 MB	VGA; SVGA with 256 or more colors suggested	Windows 98/95

Installation

InQual-S cannot be run from the General Chemistry Collection CD-ROM. It must be installed on a hard drive using the *JCE Software Setup* program. See the General Chemistry Collection CD-ROM installation instructions for directions.

Getting Started

Click the **Start** button, then select **Programs**. In the list of programs, select **JCE Software**. Click **InQual-S**.

The title page shown in Figure 1 appears. The first time you use the program you should click the **View Preamble** button and read the information as shown in Figure 2. Click the **Choose Sample** button to proceed.

To use InQual-S effectively, you should have a printed copy of the five flowcharts for InQual-S found in the file Flowchar.pdf. The flowcharts are headed Sample, Group I, Group II, Group III, and Group IV. You also need some blank paper and a pen or pencil so that you can keep a record of the saved solutions and precipitates obtained as you proceed. Without notes, it can be very difficult to keep track of solutions and precipitates. The same is true in the laboratory; when several containers and their contents are generated during a procedure they must be labeled carefully to avoid confusion.

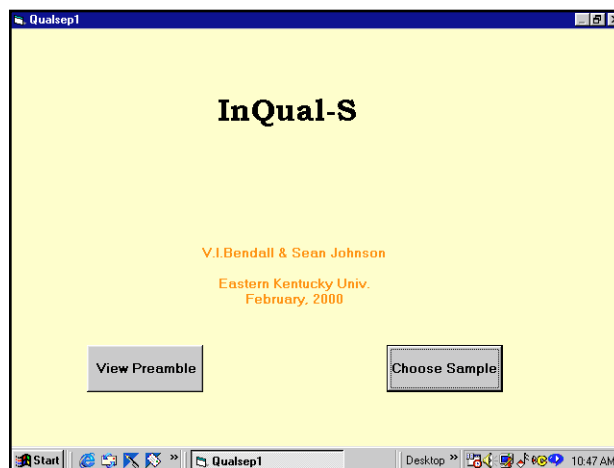


Figure 1. The opening screen of InQual-S

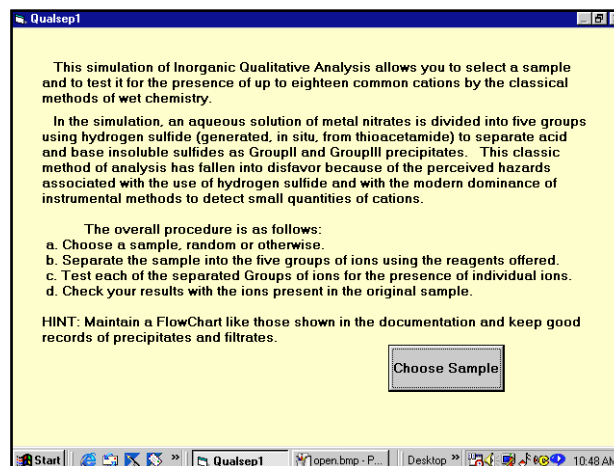


Figure 2. The Preamble is an introduction to InQual-S.

To exit the program at any time press the **ESC** key.



If you leave the program before completing your separation and identification, you will have to start completely over with a new sample. You cannot save samples for later analysis.

Refer to the User Directions if you have difficulties using InQual-S. No on-screen help is available. If you need additional help, consult your instructor.

User Directions

After clicking the **Choose Sample** button (see Figs. 1 and 2), the ChooseSample window, shown in Figure 3 appears. Select the contents of your sample solution by clicking *known* metal ions in two columns on the left side of the screen or *unknown* mixtures in the column on the right side of the screen. A *known* solution is useful when you wish to see what a given reagent does when reacted

with an ion or mixture of ions of known composition. So, for example, if you want to know if silver ion reacts with chromate anion to give a colored solution or precipitate, starting with a solution known to contain silver ion facilitates that. If you make a mistake or change your mind while preparing your sample, click the red **Oop's Start Over!** button and start over. The examples in the following instructions assume that you have clicked the **All 18 Ions** item in the list of knowns. When you have completed your selection, click the green **Start Group Separation** button.

The next screen you see is shown in Figure 4. There is a test tube containing your sample, a menu on the right side of the screen and a colored strip on the immediate left of the tube. The colored strip represents a piece of pH paper and its color reflects the pH of the sample solution. It is pink at the start because the cations are present as their nitrates and a trace of dilute nitric acid was added to keep them in solution. A drop counter just to the left of the menu lets you select the number of drops of reagent to add with up and down-pointing arrows.

Click a menu item to perform appropriate operations on the sample. You are free to choose any reagent or operation in the menu and to do them in any order you desire. However, the recommended order is that outlined in the flowcharts file ([Flowchar.pdf](#)). Start with the flowchart headed "Sample".



Follow the directions in the flowcharts *exactly* if you want a good analysis. The difference between 6 drops of 6M aqueous ammonia and 6 drops of 15M aqueous ammonia is 54 mmols of reagent and such differences can be very important. Also, the result of errors may not show up immediately. Of course, it can be interesting to see what happens when you add the wrong reagent or the right reagent in the wrong amount. InQual-S is designed to let you do that.

Examine the flowchart from the top down. Alongside each vertical line are instructions that tell you which operations to perform upon the sample in the test tube and the order in which to do them. Following the word "Filter" in the flowchart instructions the path divides. This indicates that a solid precipitate may form and should be separated from the remaining solution. One path leads to

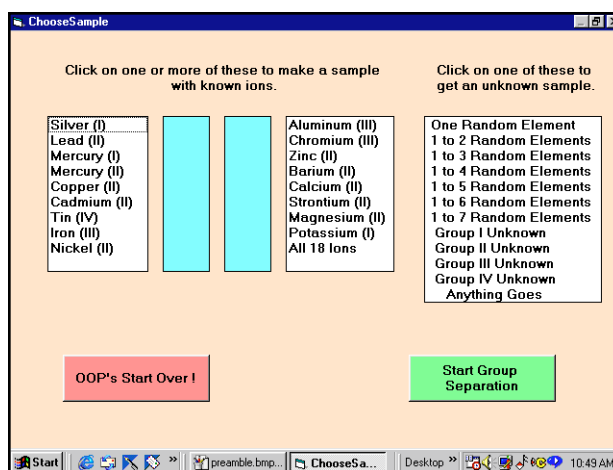


Figure 3. ChooseSample window allows you to select the sample of known or unknown ions.

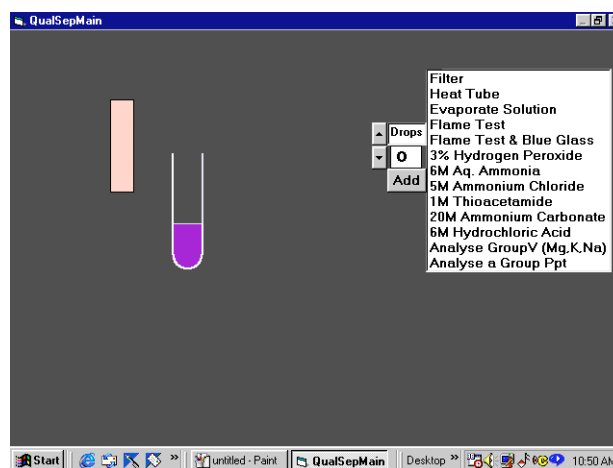


Figure 4. The beginning of Group separation.

an arrow that is terminated by a box that contains formulae or ions in bold type. These are precipitates (solid portion) that, in the Sample flowchart, are labeled "Group I". The other path leads to another vertical line with more operations to carry out upon the filtrate (liquid portion). As you move down the chart you will see similar divisions upon filtering for Groups II–V.

The first direction on the Sample flowchart is "5d 6M HCl", which means to add 5 drops of 6M hydrochloric acid. To do so, click **6M Hydrochloric Acid** in the menu to select it, and then click five times on the up-pointing arrow of the drop selector to specify five drops. Next, click the **Add** button. A simulated dropper appears above the test tube (see Fig. 5) and releases five drops of reagent into the tube. As the drops enter the solution, the pH paper becomes deeper red and a white precipitate appears. This precipitate contains the Group I ions, silver, mercury(I), and lead. (If you did not select a sample that contained one or more of the three cations that have insoluble chlorides you will not see a precipitate.)

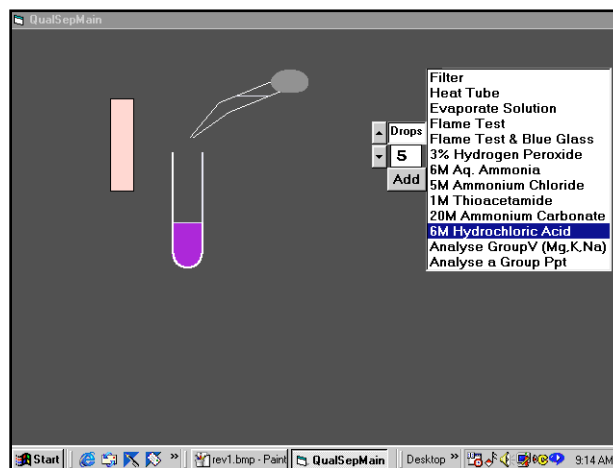


Figure 5. Adding 5 drops of hydrochloric acid to the sample.

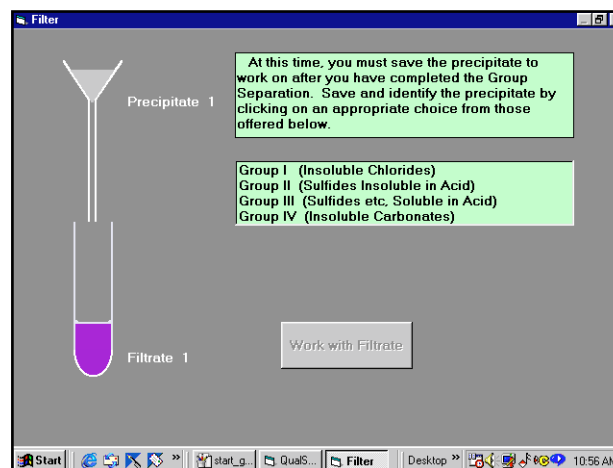


Figure 6. Filtering the Group I precipitate.

The second direction on the Sample flowchart is "Filter". Click **Filter** in the menu and you will see a stylized filtration apparatus as shown in Figure 6. The funnel contains the white Group I precipitate and the test tube below contains the filtrate. Save the precipitate by clicking one of the four choices offered. The intended choice is **Group I (Insoluble Chlorides)** but InQual-S allows you to choose another group if you wish. After the precipitate is saved, the **Work with Filtrate** button becomes active. Click the button, and you return to the screen shown in Figure 5. The test tube now contains only the filtrate.

The next item on Sample flowchart now is "2 d H₂O₂". Click **3% Hydrogen Peroxide** and add 2 drops to the test tube. When you do so, nothing appears to happen because no reaction occurs at this point. (However, if you had dichromate ion in your sample at this point because you did not follow the recommended analytical scheme, it would have been converted to Cr(III).)

The next direction is "Evaporate". In the menu, click **Evaporate Solution**. Your sample is now in an evaporation dish and is being heated by a Bunsen burner as shown in Figure 7. As you wait, the solution is evaporated and, when evaporation is complete, the burner disappears from the screen. When you click **6M Aq. Ammonia**, the next reagent listed in the flowchart, (or any other item in

the menu) the residue from the evaporation is returned to the test tube automatically.

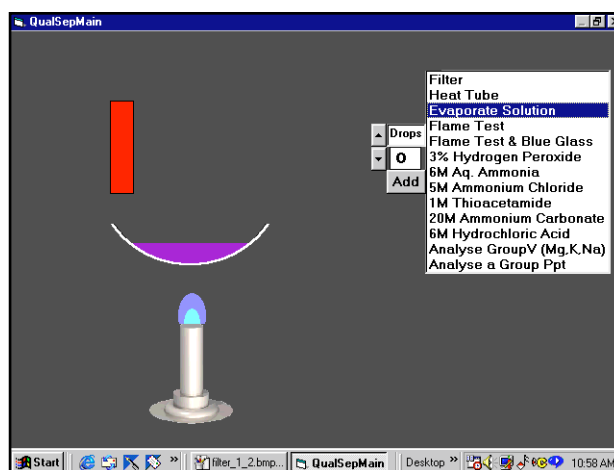


Figure 7. Evaporation.



You can interrupt an evaporation or stop heating a sample, (heating a sample is discussed later in the User Directions) at any time by clicking any other choice from the menu. If you do not allow sufficient time for an operation, however, the heating may not decompose intermediate species and later results may be confusing. It is best if you allow evaporation to proceed until the burner disappears (about 30 seconds) and heat test tubes for 15-20 seconds.



The volume of solution in the test tube appears constant throughout InQual-S. It is not representative of actual laboratory conditions.

Proceed in this fashion through the Sample flowchart until you have saved the precipitates belonging to the first four Groups. The solution remaining in the tube contains the Group V ions, magnesium, sodium, and potassium. To test for these, click **Analyse GroupV (Mg, K, Na)**, the next to last choice on the menu. This will bring up a new menu of reagents for that purpose, as shown in Figure 8. Sodium and potassium ions

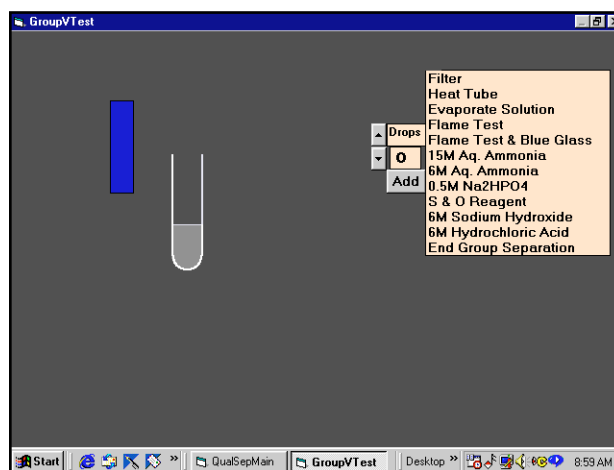


Figure 8. Group V analysis.

are detected by a flame test. You must do the flame tests first, because if you test for magnesium ion first, you will contaminate the solution with sodium ion when you add the sodium hydrogen phosphate and the sodium hydroxide.

Flame tests are done on solutions. In practice, a piece of clean platinum wire is dipped into the solution and then introduced into a blue gas flame. The flame turns a characteristic color when certain metal ions are present. To simulate this procedure, click **Flame Test** (see Fig. 9) in the menu. At this time, only sodium and potassium ions are present of those that give visible flame tests. Sodium gives a strong yellow flame test and potassium a weaker lilac colored flame test. The colored flames of other ions normally swamps out the flame color due to potassium but it can be made visible by using a cobalt blue glass

filter. The filter absorbs the colors of other flames except that of potassium. To simulate this procedure click **Flame Test & Blue Glass** (see Fig. 10) in the menu. To finish the test, click any other menu item just as you would do to finish an evaporation. After doing the flame tests, add the reagents to test for magnesium ion. Finally, choose the last menu item, **Analyse a Group Ppt** and you will be sent to a screen (see Fig. 11) that allows you to pick up any of the Group Precipitates that were saved for further analysis.

The analysis of these Group Precipitates can be done in any order. When you make your choice, InQual-S will provide you reagents suitable for that Group in a menu. If, for example, you saved the Group II precipitate under the Group III label, you will be given access to reagents suitable for analysis of Group III not for Group II. This can be interesting if done deliberately but confusing if done accidentally! This is the kind of error that students make in the laboratory when containers are improperly labeled. InQual-S gives you the opportunity to safely make the same errors.

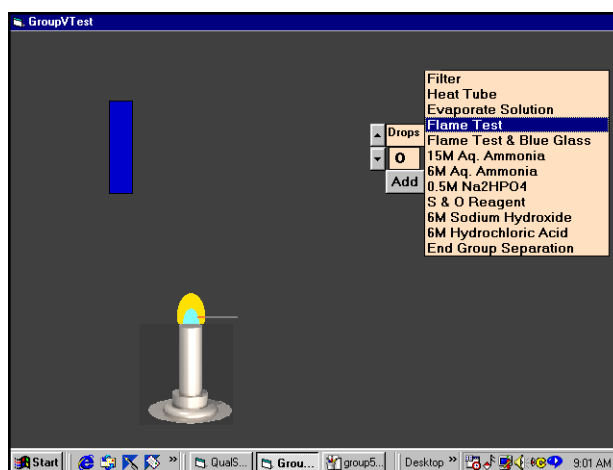


Figure 9. Flame test for sodium.

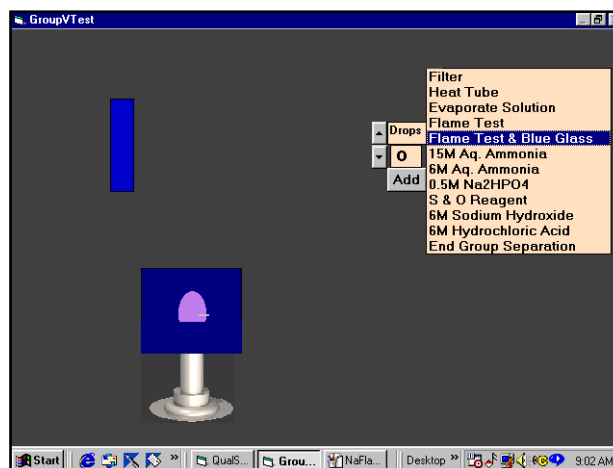


Figure 10. Flame test for potassium with blue glass.

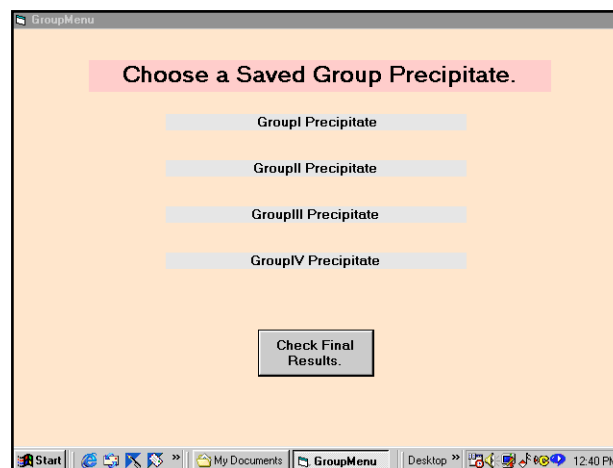


Figure 11. The GroupMenu allows you to select a precipitate to work with.



There may be a time when you want to stop the Group Separation early. For example, you elected to try a Group II unknown so that after the Group II precipitate has been saved, there is little point in continuing the separation of further Group precipitates because there should be none. There are two ways to skip the remaining separation steps. The *recommended* way is to click **Analyse Group V (Mg, K, Na)** menu item and then **End Group Separation**. Now you can work on that Group II precipitate (and/or a Group I precipitate if you saved one). You can also return and redo the entire Group Separation if you wish. The other way is to click **Analyse a Group precipitate**. The disadvantage of that method is that you cannot return and redo the Group Separation.

Suppose you choose the **Group II Precipitate** (and it is properly labeled). You should turn to the Group II flowchart and work through it. The precipitates are not saved in the same way as before. Because the order in which you work on intermediate precipitates and filtrates is not fixed, there is no simple way for the computer to tell you which intermediate is which. You must make notes of the label and color of each saved intermediate as you go along.



Note the color of each saved precipitate and solution. The simplest place to do it is on the flowchart at the point where the precipitate was saved. Note the computer label for each saved precipitate and filtrate within each Group analysis. Keeping the identity of each saved material straight is vital.

There is a feature of the Group flowcharts that does not appear on the Sample flowchart. It is text in bold type that is in parentheses, but not in a box. These are species that would have appeared at that point in the analysis if their parent metal ion had been present in the sample.

Group flowcharts also include instructions to heat the test tube, "Heat". To start heating, click the **Heat Tube** item in the menu for the group separation. A burner appears under the test tube as shown in Figure 12. Allow the heating to continue for 15–20 seconds, then click any other menu item to stop heating.

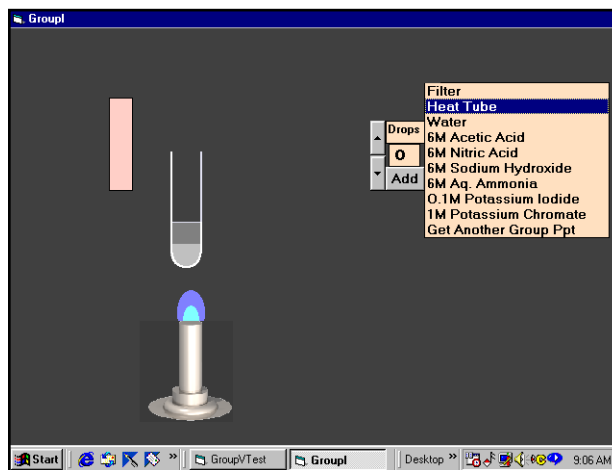


Figure 12. Heating the test tube while working with the Group I precipitate.

When you have identified all the ions present, go to the GroupMenu (Fig. 11) and click **Check Final Results** button to go to the Revelation window (see Fig. 13a), and then click **Show me the Ions present**. The ions are revealed as shown in Figure 13b. If you wish, you can return and redo the analysis of one of more of the Group precipitates. You can redo the Sample separation too, but the Group precipitates will not be saved. After checking your results, you can exit the program by clicking **Leave Program**.



If you leave the program before completing your separation and identification, you will have to start completely over with a new sample. You cannot save samples for later analysis.

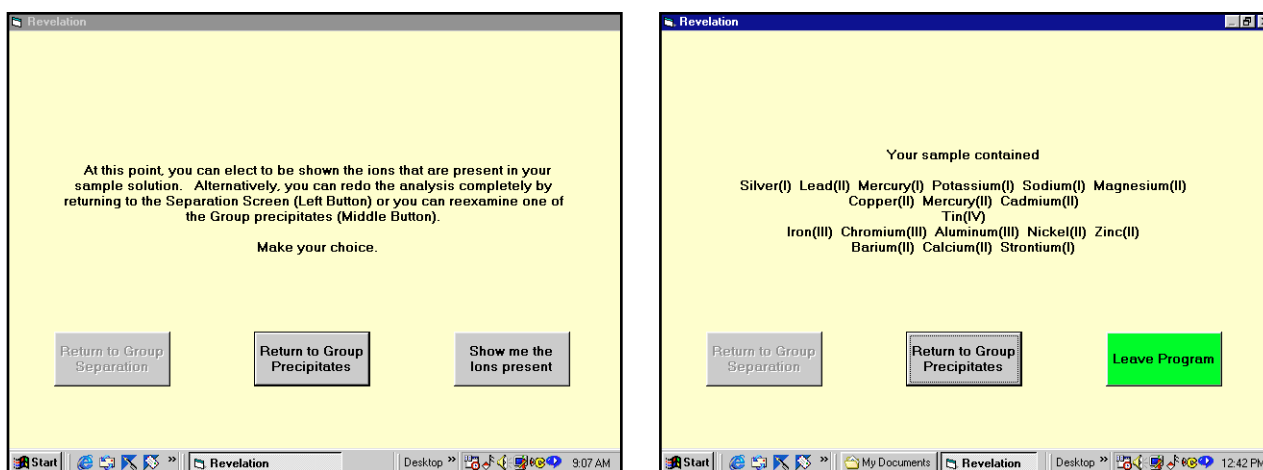


Figure 13 a and b. The Revelation screen allows you to see the ions that were present in the sample (Fig. 13a, left) and allows you to exit the program (Fig. 13b, right).



To truly appreciate the chemistry behind the reactions demonstrated in this software, you should have available a text of inorganic qualitative analysis. This software closely parallels the separation scheme described in the text by Hogness, Johnson & Armstrong (*1*), but any similar text should include the majority of the reactions found here.

Laboratory Notes

The interactions of 18 cations and more than 28 reagents are handled in this software. Since you can end up with any of the possible combinations, it was deemed unreasonable for the computer to attempt to keep track of all the equilibria, concentrations, and solubility products as well as the colors of solutions and precipitates. Compromises were made.

InQual-S keeps track of:

- The presence or absence of a cation or anion in solution or precipitate, but not its concentration.
- The color of solution and precipitate based upon a set of rules that depend upon the colored species present and combinations of those colored species.
- Temperature of the reaction container as hot or cold.
- The acidity of the solution as available protons and basicity as available hydroxide. The software does not keep track of the true pH of the solution.
- Ammonia present— assumed to be ammonium ion in acidic solution and ammonia in basic solution.

The chemistry of most interest in qualitative analysis appears as a solution changes from acid through neutral to basic and vice-versa. Big swings from very acid to very basic conditions, and the reverse, are seldom the objectives in an inorganic qualitative analysis scheme. InQual-S is intended to function well in that narrow range of conditions near neutrality. It is assumed that a user who has a very acidic or basic solution is usually interested in getting back close to neutrality as quickly as possible.

For example, if one drop of $(\text{NH}_4)_2\text{CO}_3$ is added to a very acidic solution, the software assumes that the user wants to neutralize the acid and buffer the solution close to neutrality. So, that one drop of carbonate will bubble vigorously, but the next drop may not, no matter how much acid was present originally.

This example is just one case that demonstrates that this program is a simulation and not a replacement for the laboratory experience. Other differences from reality are:

- a. Precipitates do not separate neatly to the bottom of a solution.
- b. Precipitates do not appear instantly nor redissolve instantly.
- c. Precipitates cannot be cleanly filtered from solution nor are they always easy to wash clean.
- d. The volume of solution in the laboratory is not constant. The solution has been kept at constant volume for convenience of programming and for the user. Too little solution and the color of the solution may be masked by a precipitate; too much solution and the tube might overflow as extra reagents are added. This disparity is obvious after a solution has been evaporated. Its volume in the test tube appears unchanged.
- e. The colors of mixed solutions and precipitates may be incorrect. Anticipating every conceivable combination of cations and reagents present is not possible. The necessary compromises may not give a good color match with reality in all cases.
- f. The depth of color of solutions is exaggerated. At the concentrations that are used in the laboratory, the color due to colored cations such as Fe(III) is very faint.

Troubleshooting

If you experience any difficulty in running InQual-S, first verify that you have the minimum hardware and software required to run the program. Hardware and Software requirements for InQual-S may be found on Page 2. Second, consult the relevant section of the User's Manual for assistance.

Problem Reports

If the problem is not addressed in the manual and all required hardware and software are present and in working order, contact the *JCE Software* office for technical assistance. For quickest response, call, send a FAX, or an email message.

Instructor Notes

Each student will need a copy of those flowcharts found in the file [Flowchar.pdf](#) while he/she is using InQual-S. Adobe Acrobat Reader is required to view and print the flowcharts. You can download a free copy of Acrobat Reader from Adobe at <http://www.adobe.com>.

The CHEAT

Students may frequently encounter a precipitate or solution that was not anticipated. They may conclude that the software is at fault. Before reaching that conclusion, try the built-in CHEAT function. It is suggested that you reserve the CHEAT for your use alone. It is not described in the User Directions for this program.

To use the CHEAT function, click immediately above the top left side of the menu box that offers the reagents. The active area is a box about 1 cm square, as shown in Figure 14. You may have trouble finding it at first. A pattern of colored dots appears at the top left of the screen (also shown in Fig. 14). The pattern matches the Matrix of Ions, Cations and Other Species that follows this section. A White dot means that the species is absent. A Red dot means that the species is in solution. A Blue dot means that the species is present in the precipitate.

For example in Group II, if you did not evaporate the solution after 3% Hydrogen Peroxide was added, the excess peroxide was not boiled out and may remain to oxidize Cr(III) to Cr(VI) in basic solution. Now the solution may be unexpectedly yellow and metal chromates may precipitate at an inconvenient moment. The CHEAT can help you diagnose such problems.

Turn off the CHEAT by clicking on the same area as you did to turn it on.

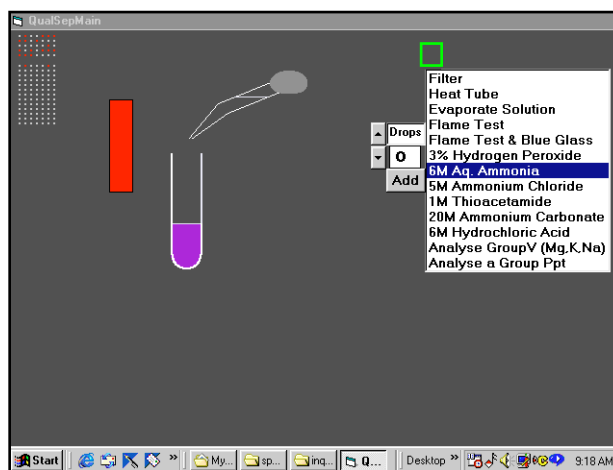


Figure 14. The CHEAT matrix is shown in the upper left corner. The green box shows the approximate area clicked to turn on the CHEAT feature. It is *not* marked in the program.

Matrix of Ions, Cations, and Other Species

Use this matrix with the CHEAT function in InQual-S to identify species present in solution and precipitate.

Ag ⁺	Pb ²⁺	Hg ₂ ²⁺	NH ₄ ⁺	K ⁺	Na ⁺	Mg ²⁺
Cu ²⁺	Hg ²⁺	Cu ⁺	Cd ²⁺	Bi ³⁺	Bi ⁵⁺	
As ³⁺	As ⁵⁺	Sb ³⁺	Sb ⁵⁺	Sn ²⁺	Sn ⁴⁺	
Fe ³⁺	Mn ²⁺	Cr ³⁺	Cr ⁶⁺	Al ³⁺	Ni ²⁺	Zn ²⁺
Ba ²⁺	Ca ²⁺	Sr ²⁺	Fe ²⁺			
F ⁻	Cl ⁻	Br ⁻	I ⁻	CO ₃ ²⁻	NO ₃ ⁻	SO ₄ ²⁻
OH ⁻	OAc ⁻	CNS ⁻	CrO ₄ ²⁻	HPO ₄ ²⁻	NO ₂ ⁻	SO ₃ ²⁻
O ²⁻	S ²⁻		Cr ₂ O ₇ ²⁻	PO ₄ ³⁻	ClO ₃ ⁻	S ₂ O ₃ ²⁻
		Fe(CN) ₆ ³⁻	Fe(CN) ₆ ²⁻	C ₂ O ₄ ²⁻	MnO ₄ ⁻	NO ₂ ⁻
Dimethylglyoxime	Aluminon	H ₂ O ₂	Hot Water	NH ₄ OH	Aqua Regia	
HCl	HNO ₃	H ₂ SO ₄	Acetic acid			
Thioacetamide	N(C ₂ H ₄ OH) ₃					
Na ₂ SnO ₂	Na ₂ S ₂ O ₃	BiO ₃ ⁻	MagnesonS&O Reagent		MnO ₂	
Hg	Fe	Al	Bi			

Reagents

The following table lists the reagents available in InQual-S.

6M HCl	0.5M KOH	1M Thioacetamide	Fe Wire
12M HCl	6M NaOH	3% H ₂ O ₂	Al Wire
2M H ₂ SO ₄	6M NH ₄ OH	1M K ₂ Cr ₂ O ₄	Aluminon
18M H ₂ SO ₄	15M NH ₄ OH	0.1M KI	S ₂ O Reagent
3M HNO ₃	3M NH ₄ OAc	0.1M SnCl ₂	1% Dimethylglyoxime
6M HNO ₃	2M (NH ₄) ₂ SO ₄	0.1M HgCl ₂	
16M HNO ₃	5M NH ₄ NO ₃	0.5M BaCl ₂	
Aqua Regia	20M (NH ₄) ₂ CO ₃	0.5M Na ₂ HPO ₄	
6M Acetic Acid	5M NH ₄ Cl	1M KSCN	
	0.2M (NH ₄) ₂ C ₂ O ₄	50% Triethanolamine	

Metal Ions

The following table lists the cations included in InQual-S.

Ag ⁺	Cd ²⁺	Hg ₂ ²⁺	Na ⁺	Sr ²⁺
Al ³⁺	Cr ³⁺	Hg ²⁺	Ni ²⁺	Zn ²⁺
Ba ²⁺	Cu ²⁺	K ⁺	Pb ²⁺	
Ca ²⁺	Fe ³⁺	Mg ²⁺	Sn ⁴⁺	

Citations

- Hogness, T. R.; Johnson, W. C.; Armstrong, A. R. *Qualitative Analysis and Chemical Equilibrium*, 5th ed.; Holt, Rhinehart and Wilson: New York, 1966.
- King, E. J. *Qualitative Analysis and Electrolytic Solutions*; Harcourt, Brace: New York, 1959.

Frequently Asked Questions About InQual-S

1. How can I get a printed copy of the screen?
Printing capability is not included in InQual-S. The only way to print a copy of the screen is to do a screen capture (press the **Print Screen** key) then paste the result into a graphics program capable of printing.
2. How can I save an unknown and return to it at a later time?
You cannot. It was intended that the user run the software as a practice exercise before entering the laboratory. A complete run through a single unknown from start to finish usually takes about 30 minutes. There is little advantage in not completing the program in one sitting.
3. Can the software be adapted to save student names and unknowns so that an instructor could use it to grade student performance?
It cannot be done easily and was never the intent of the author. InQual-S was intended as a practice exercise for students. It is a simulation and should not be used to replace the laboratory exercise.
4. Why use five files to save data rather than one bigger unified one?
This was a programming decision. It was easier to debug the software with separate files. Each file is very small containing, at most, 22 digits and so the total space used is very small.
5. How do I leave the program early?
There are three ways. The fastest is to Press **ESC**. The most orderly is to get to the Group Menu, see what ions were in the sample and exit. The sloppiest is to click on the taskbar icon at the far right. You may have to click it more than once but you can exit in that manner.
6. How do I access and use the CHEAT?
Click above a reagent menu block on the extreme left side. There is a 1 cm. square area there that is active. Once you find it, you should have no trouble finding it again. Another click on the same area will turn the CHEAT off again. It is used with the array supplied with the documentation. A white spot is a blank array position. A red spot represents an ion or species present in the solution. A blue spot represents an ion or species present in the precipitate. Cations are in the 5×8 block at the top of the array.
7. Why was the CHEAT done this way?
It was written as a debugging aid as a quick way to show all the species present at any time. Only after the code was completed was it decided to include it for instructor use. It was left in this form so that it was not immediately obvious how students can reach it nor how to read it if they saw it.
8. What happens if a student saves a Group I precipitate under the Group II heading and why does the software allow that to happen?
What will happen is that when the student chooses the Group II precipitate (which now contains the Group I ions), the reagents offered are those for Group II analyses. This can lead to strange behavior, confusion and frustration. It was done this way because it mimics what happens in the laboratory if precipitates and solutions are mislabeled. Allowing opportunities to make mistakes is an essential part of any laboratory simulation.
9. I would like to see what happens when a Group I ion (Ag, Hg(I) or Pb) is treated with a reagent which is not offered when I am analyzing Group I, but is available to Group II. Can I do that?
Yes, but it takes a little maneuvering. Precipitate your ion with a reagent available to you, filter it and save it as a Group II precipitate. Go to the Group Menu and choose the Group II precipitate. Now the Group II reagents are available. However, while the author has attempted to include solubility rules to cover many possibilities, your combination of species may not be covered.

10. The behavior of the ions is nothing like the behavior that I expected of these species. What can I do?

First, make sure that the result is repeatable. It is easy to add the wrong reagent (eg. 15M ammonia rather than 6M ammonia) in the wrong amount so that the acidity and ammonia content is not that intended, etc. If you can repeat the problem, then look at the CHEAT and see if the ions present—soluble and insoluble—are what you expected. If the problem cannot be resolved in this way, report it to *JCE Software*.

11. Why are the reagents not listed in alphabetical order in the menu?

The order was intended to be such that, if the user proceeds through the separation in a logical manner, the reagents would be in the order in which they were needed. However, some reagents are needed twice at widely different locations in the separation scheme, and it seems reasonable to put 6M HCl next to 12M HCl. With limited space to describe a reagent, formulae are used in some lines and names are used in others, so alphabetical schemes are awkward. Eventually, it was reduced to personal preference and the author liked this order.

12. How long do I wait when I heat? The evaporation takes too long. Can I stop it early?

In some cases, the heating causes reactions that alter, or destroy, a species. If the heating is cut short, those reactions may not be completed and subsequent procedures may not work as expected. It is best to heat for a minimum of ten seconds before stopping and to allow the evaporation to go to completion.

13. On occasion, I get precipitates before I add a reagent.

This may occur when the reagent to be added was added earlier and excess reagent has remained in the filtrate. This is most likely to occur when thioacetamide was added to precipitate sulfides and is later added to precipitate sulfide again. Heating thioacetamide solutions normally destroys any excess. However, the management of sulfide and thioacetamide concentrations turned out to be a very difficult programming problem especially when users are allowed to add any reagents in any order. Compromises had to be made and the result is that sulfide ions tend to remain in solution longer than they do in the true laboratory, with the effect shown.

14. It is annoying to have to click a button 12 times to add 12 drops of a reagent. Why not allow the user to enter 12 as the number of drops and press **Enter** to add them?

Numbers can be typed into the number drop field. You must click the **Add** button to add the drops.

15. Why are the precipitates simulated? Why not use photographs of a test tube with precipitates as they truly are?

This is practical only if the number of precipitates, and when they appear, is tightly controlled. In this simulation, the user can enter any combination of reagents they desire. The number and kind of possible precipitates is very large. To cover all possibilities would demand an equally large number of photographs and complex coding to decide which to show. The user does not expect simulated images to exactly match reality but does expect photographs to do so.