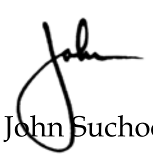
Introduction

One main goal of any course we teach is to capture student interest. For a liberal arts chemistry course, achieving this goal is a special challenge. Not only is the course usually offered as an elective, but most of these students have never had a significant interest in science and many are intimidated by it.

How do we capture and maintain the interest of our liberal arts chemistry students? How do we also provide our students with the essentials of a field that has had a revolutionary impact on the way we live? There is a variety of teaching techniques that assist us toward these goals. Many of these techniques are discussed within this instructor's manual. I believe, however, that it is typically not the curriculum but the enthusiasm and energy of the instructor that has the greatest bearing on the students' willingness and desire to learn. Accordingly, it makes sense to focus on what it takes to capture and maintain our own interests in teaching as well as the interests of the students we teach. One of the main goals for this instructor's manual, therefore, is to show how you might use *Conceptual Chemistry* and its supplements to make your presentation of chemistry to the liberal arts student an enjoyable and rewarding experience.

Thank you for your interest in *Conceptual Chemistry*. I look forward to hearing from you, especially regarding any corrections needed in the textbook, this instructor's manual, or any of *Conceptual Chemistry*'s supplements. Good Chemistry to you!



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Why Use *Conceptual Chemistry*?

The teaching of chemistry is supported when the instructor balances the principles of chemistry with the application of these principles to real-life situations. Finding this balance is one of the key challenges to the creation of any chemistry course, but especially to the creation of a course designed to meet the needs of the student whose primary interests lie outside the realm of the sciences. *Conceptual Chemistry* and its many supplements are tools that can help you to find this proper balance. Throughout this curriculum, the applications of chemistry, both usual and unusual, are thoughtfully woven into a sturdy backbone of concept development.

Strong Concept Development

Conceptual Chemistry recognizes the vertical structure associated with the learning of chemistry. For example, one needs to learn about atoms in order to understand molecules, which must be understood before learning about intermolecular attractions. Accordingly, there is a natural order to learning chemistry and this order is generally from simple to complex. Furthermore, because concepts build upon previously learned concepts, the process of learning these concepts cannot be rushed. Squeezing the ideas of atoms, molecules, and intermolecular attractions into a single chapter is simply too much too soon. To optimize learning, these concepts should instead be introduced at a leisurely pace, such as over the course of several chapters.

The learning of chemistry concepts is also optimized when the concepts are presented using a “spiral” approach. In such an approach, just enough depth is initially provided to allow insight into a particular application. The concept is then revisited in a subsequent chapter where further depth is provided to allow insight into yet another application. Repeated introductions to the same concept, but in a different context, allows that concept to “sink in.” This approach is fundamental to how the brain learns new information. An example familiar to most of us is the learning of someone’s name, which often happens only after meeting that person several times. Accordingly, within *Conceptual Chemistry*, the student will find key concepts such as the periodic table, chemical bonding, mass conservation, nanotechnology, solutions, and mixtures revisited several times over

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the course of several chapters. Importantly, each reiteration not only consolidates a basic understanding, it also builds upon that basic understanding.

Strong Integration of Chemistry Applications

Conceptual Chemistry recognizes that any interest we might have in the concepts of chemistry is intricately married to the real-life situations these concepts are able to explain. Water is a bent molecule. So what? Well, because it is bent, one side is slightly negative and the other slightly positive, which means water molecules stick to each other quite well. This in turn explains why oil and water don't mix and why it takes so long to heat a pot of water, which is the same reason our oceans protect us against runaway global warming. Strong concept development, therefore, lays a foundation for understanding the happenings of our immediate universe. In *Conceptual Chemistry*, concepts are developed only in the context of what they are able to explain.

The *Conceptual Chemistry* textbook further showcases the applications of chemistry with frequent FYI paragraphs and the periodic "Connection Question" puzzlers set in the margins. Questions at the start of each section and at the back of each chapter also prod students to think about concepts in the context of real-life situations. Furthermore, chemistry-related topics, such as the Superfund Act, forensic science, or fracking technology, are highlighted within the "Contextual Chemistry" essays appearing at the end of each chapter.

Beyond Concept Development and Chemistry Applications

It is said that the true value of any academic course is the flavor that remains after all the facts and figures have been forgotten. You can consider your course a success, if in the distant future, your former students recall your class as being "fun." In addition, however, a chemistry course is fertile ground for an even higher calling, which is a student's personal growth—intellectually, emotionally, and socially. This idea is addressed in my notes to the instructor in the frontmatter of the textbook. What is not addressed there, however, is a thorough discussion of a wonderful means by which this higher calling and all our other goals can be met with resounding success. I am referring to the techniques of "student-centered learning." Turn the page to learn more!

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The Student-Centered Class

Most students expect class to consist of lectures plus demonstrations. A great class is one where the lectures are engaging and the demonstrations are many. A boring class is one where the instructor makes little attempt to be animated and the demonstrations are nonexistent. Either way, the students remain seated, equipped with pen and paper to record the events as accurately as possible so that they may be studied in more detail later in some quiet privacy.

This traditional class format can be effective at helping students learn. However, educational research suggests that better results are obtained when the instructor is able to make the students active participants. Check-Your-Neighbor-type questions are a good starting point. This is where the instructor asks a multiple-choice question of the class. Students then discuss possible answers amongst themselves before responding as a whole. In taking this interactive approach a step further, students can use class time to collaborate on projects, worksheets, or hands-on activities—all the better if this curriculum is designed to assist students in articulating what they think they have learned. Students themselves can be given access to the science demonstrations and be required to explain the underlying concepts. Any lecture presentation they receive is short and sweet, and provided "on the fly" in response to their specific needs. In such a scenario, students find themselves in the spotlight. They find that class is akin to a grand study session where the instructor is their study leader, who migrates from team to team providing expert assistance on demand. These are the hallmarks of what we call a "student-centered" class. Lectures are minimized for the sake of increased class participation.

Students Must Come Prepared

The prerequisite to an effective student-centered class is that the student arrives to class prepared. Assignments need to have been read *beforehand* and exercises attempted *beforehand* such that a hazy understanding has already begun to take form. But as any instructor knows, student resistance to coming to class prepared can be intense. How, then, do we motivate students to come to class prepared? There are numerous tools. First of all, it is vital that the textbook be as user-friendly as possible—students should enjoy reading it!

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This, of course, has been one of the main goals in developing the *Conceptual Chemistry* textbook. The student should be able to learn about chemistry concepts on his or her own with minimal assistance from the instructor. This, in turn, supports the instructor who is wishing to move toward a student-centered class.

Another important tool for encouraging students to study is a short quiz given at the beginning of class, or even *before* class with the quiz posted on the course website. This quiz should assess students for their familiarity, not their expertise, of the material about to be covered. Following the quiz and a brief introduction, students work on various activities within teams. If a student comes ill-prepared, he or she then faces perhaps one of the greatest motivators: peer pressure. Of course, not everyone can always come prepared. Students know this and are generally forgiving and welcoming of all input either weak or strong. But they quickly come to realize that with the spotlight on them, it is difficult to hide, even in a large lecture hall.

If you are ready to make your classes more student-centered, you need to let your students know right away how this approach will help their learning, provide for an enjoyable experience, and, ultimately, improve their test scores. Notably, the interpersonal skills gained through collaborative learning is an added plus. Also, students are much more willing to participate if the in-class activities are unequivocally related to the quizzes and exams they take.

Lastly, a student-centered approach consumes a large portion of class and so the instructor has less opportunity to deliver content, though a greater opportunity to facilitate the learning of content. Consequently, in order to keep pace with a traditional syllabus, the instructor needs to decide whether there will be material on exams not covered directly in class. If so, the instructor should be mindful to reserve class time for the more challenging concepts.

Students Are the Players and You Their Coach

There is great potential in transforming a class from one geared toward passive learning to one geared toward active learning. What is needed is a willingness to get creative and to push the responsibilities of learning more squarely on the student. The role of the instructor is to provide students with good questions rather than good answers. We can think of students as team players out on the field doing all the hard work, which means

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finding answers for themselves. We are their coaches here to direct their learning efforts. Sometimes the best way to do this is by knowing when to cheer and when to remain silent.

Getting Started

So, is it better to retool one's teaching methods in a single semester or to explore new activities one at a time over many years? Revolution or evolution? If you're like most of us, the thought of revamping everything within a single semester is most undesirable. Indeed, implementation of any student-centered activity requires a fair amount of trial and error. Imagine implementing many new activities all within a few weeks only to have them fail miserably. This would be a disservice to your students, to yourself, as well as to the student-centered learning approach. The best practice is to introduce only the activities you think will work best for your students in a time frame that allows for successful development. Too much too soon can be self-defeating.

The techniques presented here are a select few that I know work well. Some work for large classes while others are better suited for smaller classes. Chances are that you have already implemented techniques of your own or that new ideas will soon be coming to you as you forge ahead. Also, you need look no further than journals, such as those of the National Science Teachers Association, the *Journal of Chemical Education*, or through the web to find a constant flow of student-centered learning innovations. Some good references are included at the end of this essay. The point to be made is that student-centered learning is fertile ground, even for those of us who have already nailed down our lecture presentations and are wondering what to do next.

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Student-Centered Assessment Techniques

(What students can do to articulate what they think they've learned)

The Concepts Inventory

The Concepts Inventory is a short test taken by students at the beginning and end of the semester to measure increased understanding of basic concepts. Inventory questions should reflect concepts that the instructor hopes the ideal student will learn by taking the course. A good inventory will also include questions that address common misconceptions. At the end of the semester, the same Concept Inventory is given or the same questions can be snuck into the final exam. Typically, student scores on an inventory don't improve by very much. This can be explained, in part, by the idea that it is most difficult to lead students away from their well-entrenched misconceptions.

The Minute Quiz

At the beginning of class it is valuable to give students a single-question quiz that assesses whether or not they have come prepared. Such a quiz might be designed to test for a *familiarity* of the material about to be covered rather than an *understanding* of this material. Note that these quizzes needn't take much time. They may be called "minute quizzes" because the students have only one minute to answer. They can put their quiz, which is printed on a narrow strip of paper, into a blue box that gets passed around the class. A right answer is worth 25 points while a wrong answer is worth 10 points. If a student opts not to put their quiz into the blue box, they may hold on to their quiz until the word is given that they are allowed to open their notes, their textbooks, and talk with their neighbors about the possible answer. After another one-minute period they place the quiz into a red box which means they get 20 points for a right answer and 15 points for a wrong answer. Students soon catch on to their best strategy. With this system, the prepared students are preferentially rewarded. By the end of the semester, all of the quiz scores add up to a significant portion of the course grade, which is added incentive for students to come to class prepared.

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Collaborative Exams

For a real learning experience, an exam may be offered in three phases: individual, team, and class. In the first phase each student takes the exam individually while also filling out a duplicate exam that contains their answers but not their name. Assessment for this individual effort should be weighted the greatest. For example, each question may be worth 5 points, while for the second phase each question is worth 3 points, and for the third phase just 1 point.

A 10-minute warning is given to ensure that all students finish with the first phase at about the same time. Exams are turned in while the duplicate exams are spread out onto a broad table. Students then congregate into their teams to take the exam again, but this time working together and with resources, such as the textbook. They are also permitted to send a scout to inspect the duplicate exams to see how the rest of the class answered specific questions. Each member of the team should have a copy of the exam, but only one exam is to be turned in for assessment. Meanwhile, the instructor and/or TA is quickly grading the individual exams. (Use a Scantron if available.) The goal is to post the class average before the teams finish their team exams. This feedback allows teams to gauge the value of the displayed duplicates. A quick alternative to grading all the exams is to post the average grade of five random individual exams.

After teams turn in their team exams they are ready for the third phase in which they take the exam yet again, together, as a class. The instructor records the class's answers on a single master copy of the exam. Teams vote for an answer by holding up color-coded flash cards. Teams are allowed to argue their answers, but majority wins. If there is a tie among teams, then there is a recount after some healthy debate. After each class answer is recorded, students are then told the correct answer, which is often followed by cheers or groans.

The length of the exam is determined by the duration of the class. For a 75-minute class, the exam can contain up to 25 questions. For a 50-minute class, the exam should be narrowed down to about 15 questions. Timing is an important factor. In particular, students should finish the first phase of the exam all at about the same time. Slower students can be encouraged to come to class early for a head start. It is also helpful to have a second room where slower students can go in the event they need another 5 or 10 minutes to finish the first phase. For the second phase, which is the team phase, ithelps to

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include a “toughie” bonus short-essay question at the end of the exam. This is useful for teams who finish early—it keeps them busy while other teams are still working on the regular questions. There is not always sufficient time to have the third phase, which is when the class takes the exam together as a whole. To expedite the third phase, the instructor lays out the team answers so he or she can see all the team answers at a glance. Instant credit is given to questions that are unanimously correct. This allows the instructor to move on to some of the more difficult questions, which tend to have different answers from different teams.

By the time the class period is over, students have taken the exam three times andknow their final score. Individual effort is preferentially rewarded, yet students still get the valuable experience of working together as a team. Furthermore, with such a format, the instructor is able to fill the exam with juicy, but tough questions. The individual phase of the exam, for example, may average 65 percent or less. This is balanced, however, by the team and class phases, which may run 80 percent and 95 percent, respectively, so that the overall average is within the mid-70’s. One serious drawback to this format is that it consumes a lot of paper. If each student has access to a computer, however, the paper can be replaced by online delivery, which would also assist with the intensive instant grading.

Appeals

With end-of-semester course evaluations, a number one concern shown by most students is whether or not the course was fair. Towards satisfying this need, students may be permitted to appeal any question for which they believe they deserve credit. The instructor sets up the conditions of the appeal. For example, the student’s explanation for why they think they deserve credit must be handwritten and submitted within a certain time frame. Also, only those who were actively involved in the appeal, as indicated by their signature, have the possibility of gaining points. Appeals are reviewed by the instructor in the safety of his or her home or office, where he or she may assign full, partial, or no credit. Aside from providing students a sense of fairness on your part, the appeals provide the feedback you need to modify questions that might not be worded so optimally.

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Student-Centered Learning Activities

(What students can do when the instructor is not lecturing)

Team Formations

Collaborative learning tends to work best when students are grouped together in teams consisting of either 3 or 4 students. For a team of 5 students, invariably, the fifth student takes a back seat and is less involved. For a team of 2 students, there is not a sufficient diversity of ideas. Who goes on what team is the difficult responsibility of the instructor who knows that each team needs to be well-balanced in terms of academic abilities and gender. At the start of the semester, the instructor can eyeball who goes where. Putting friends together initially is a good thing. Alternatively, the instructor can await the results of a Concepts Inventory and use student scores as the basis for team formations.

The instructor should consider new team formations after each mid-term. Students thuswork together in the same team up to the mid-term, which is collaborative as described earlier. Mid-term exam scores are then used as the basis for new team formations.

The first assignment of any team is to agree on a team name. The periodic table provides a wealth of possibilities. Team Titanium, Team Gold, and Team Einsteinium are some of the more popular choices.

Hands-On Chemistry

Within each chapter of *Conceptual Chemistry* are several home-project-type activities called Hands-On Chemistry. These brief activities, including many others found within the *Student Activity Manual* by Jeff Paradis (see page 22), are most conducive to team learning in the classroom. As you can imagine, students appreciate the hands-on exploratory nature of these activities—they really help to liven up a class. The drawback is the time it takes to make sure that each team is set up with the proper materials, and to make sure that students clean up after themselves. We need not restrict all lab activities to the lab when there are many small, safe, easy to set up activities that can also be done effectively in class.

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Practice Pages

An important supplement to *Conceptual Chemistry* are the Practice Pages, which are a set of minds-on, pencil pushing concept review worksheets. They are available for free download at ConceptualChemistry.com. The Practice Pages are designed as a study aid that students can work on outside of class. They are far more effective, however, when students work on them together as a team under the expert supervision of the course instructor, who travels from team to team to assist students as necessary. It is common that a Practice Page will prompt a question from a student that, in turn, prompts the instructor to give a short lecture presentation to the team. In such instances, neighboring teams can be encouraged to eavesdrop. This is known as "targeted teaching" and it arises not just from the Practice Page, but from nearly whenever the instructor is roaming about checking on team progress. Occasionally, it prompts the instructor to switch gears and give his or her mini-presentation to the whole class. Targeted teaching is impromptu and in response to immediate student need.

Think-Pair-Share

This technique was made popular by Eric Mazur of Harvard University in his book *Peer Instruction: A User's Manual*. A multiple-choice question is presented to the class. Students contemplate the question on their own and then commit to an answer, preferably in writing or via flash cards, so that the instructor can quickly gauge student performance. Students then discuss their reasoning with adjacent students. After student–student discussions, a second survey of answers is taken. If the responses prove satisfactory, the instructor can move on to the next concept. If students are struggling, then the instructor may decide to spend more time clearing up misconceptions.

To accommodate this technique you will find on the *Conceptual Chemistry Instructor's Resource IRC* a set of ten multiple-choice questions from each chapter. These are the same ten questions that appear at the end of each chapter of the textbook as the Readiness Assurance Test (aka RAT). These questions tend to be relatively difficult questions so that students are challenged, which is a good thing for Think-Pair

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Share.Furthermore, on the IR-DVD, these questions are encoded as "clicker" PowerPoints by which students can electronically enter their responses during class via their hand held "clickers." Not having yet used a clicker system myself, I can only vouch for my homemade flash cards, which have proven most effective.

Readiness Assurance Test (RAT)

Hands down, this is the student's favorite activity—not for the joy of it, but because it is most related to helping them perform well on their exams. The RAT is simply a trial exam given to the class before the actual exam. It helps students assess how ready they may or may not be for the exam. Everything about the RAT should be identical to the exam except that the points don't count and the questions are different. So, should the RAT questions be easier or harder? In my opinion, a good RAT is one where the students mope out of class with their heads hanging low. They feel it in their hearts that they really need to buckle down if they want to do well on the upcoming real exam. Depending on what psychology you want to use, you may or may not tell them that the questions on the RAT were relatively tough. Either way, their subsequent improved performance on the real exam can be a confidence builder, which is especially important for these students, many of whom are science phobic.

If you are implementing collaborative exams (described above) or any other new and unusual exam format, a RAT also affords you the opportunity to learn how the exam format is best implemented.

You will find that there are short RATs already given at the end of each chapter. You might consider building your RAT using these questions. Alternatively, if you formulate your own RAT questions, you might consider using some of the textbook's RAT questions for your exam to reward students who have been working with the questions at the back of each chapter.

Class Presentations with Activity Intervals

Select questions are assigned to teams of students who then have a short period of time (10 minutes) to prepare and practice articulating an answer. Students as individuals or as a team then get up in front of the class to articulate their answers in a short 2-minute

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presentation. They then ask the class if there are any questions. The instructor, meanwhile, has planted some well-thought-out questions among the audience who then ask these questions, which probe deeper into the concepts. The presenting student or students can either respond or choose to serve as moderators of a class discussion. Certain questions lend themselves to short but effective hands-on activities. After a student presentation on surface tension, for example, the class can be challenged to float a paperclip on water. Or after a presentation on condensation, the instructor can invert a steam-filled soda can in water. Students are then prompted to explain why the can imploded. Of course, if they can't figure it out, it is the responsibility of the instructor to keep quiet or provide only hints.

Questions that work well for this technique include the Think and Explain questions from the textbook. These questions also lend themselves well to study group sessions either outside of class or during class under the supervision of the instructor. A student should be reminded that if he or she understands the answer to one of these questions—if he or she really does—then he or she should be able to articulate the answer (verbally!) to someone else, such as a fellow student.

Talk to the Wall (with Self Ratings)

Students hate this activity. But that's okay because you're their coach, not their friend. Short, easy to read "Explain This" questions are posted around the classroom. There are as many posted questions as there are students, which means this works only for relatively small classes. Beneath each question is a grid that allows the student to rate on a scale of 1 to 5. To begin, each student is placed in front of a question. At the sound of a bell, all students vocalize their explanation or answer. They tend to speak softly at first, but the instructor keeps insisting for them to speak louder. Ideally, the classroom becomes quite noisy. Students must continue to articulate, no pauses allowed, until the bell rings once again. At that point they rate on the grid how well they think they did. The whole class then rotates in the same direction so that everyone is before a new question. This continues for as long as the instructor thinks is appropriate. When finished, the instructor runs around the room grabbing all the questions. Ones in which students gave themselves low marks are the ones that become the focus of subsequent class discussions.

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The main point to emphasize with students through this activity is that there is a vast difference between thinking you know something and articulating that which you think you know. A true test for understanding is whether or not the student is able to explain that understanding verbally. So when one student explains a concept to another, who benefits the most? The sender or the receiver? Likewise, who is getting the best learning experience: the young professor refining his or her lecture presentation, or the students listening to this lecture presentation? It can't be emphasized enough that, if a student wants to really learn something, a good way to start is by moving the mouth, whether to a friend or a brick wall, it doesn't matter. It is not comfortable. But that's okay. Learning isn't meant to be comfortable. The best ice skaters are the ones who have fallen down the most.

Focused Listing

On a blank sheet of paper, students write down a list of 4 or 5 terms or phrases that help to portray the content of a particular section of the textbook or of some reading assignment. This activity quickly assesses what key concepts were difficult for the student to understand or whether or not the student studied the reading assignment. A related activity described by Angelo and Cross is called "The Muddiest Point" whereby students write down what concepts from a chapter were most unclear. The instructor then uses this information to launch a class presentation (mini-lecture or demonstration) or a class discussion à la the Socratic method whereby everything the instructor says is phrased as a question.

Most Important Concepts

This activity is a variation on focused listing described above. At the start of class have each student write down (on a note card) what they think are the three most important concepts from their studies for today's class. Students need not write their names on their cards. If three concepts are too many for a student to recall, then encourage the student to include at least one. Students who haven't studied will be caught off-guard, but you can encourage them instead to write down any questions they may have. Collect those questions just before the start of the next phase of this activity, which is where students share their cards with each other (teams of 4 works well) and come to an agreement on the most important concepts. Conclude the activity by moderating the

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class to come to an agreement on the most important concepts. Use the anonymous student questions (if any) as a launching point for further discussions. Making this a regular activity will encourage students to come to class prepared.

Any Questions?

Asking the students if they have any questions is a common way of starting a class. Students typically respond with silence. A better alternative is to ask students to write down a question on a strip of paper. Tell them to be sure NOT to include their name. Collect the questions and then quickly isolate the ones you feel may be a good launching point for discussions. This may be a discussion between you and the entire class or students may be sorted into teams where they discuss the questions themselves. For the latter approach you can ask for each team to have a designated "articulator" who will stand up in front of the whole class to provide a response to the question.

A variation on this activity that works only once per semester, is to print some really good questions on small strips of paper. Then, before class, cut out each question, fold it up, and tape it under the desks of students. Start class by asking if students have any questions. If there are no questions, then all-the-better: pick a particular student and give a subtle gesture to that student saying that "well, maybe you really do have a question." With only body language, get the student to feel under the desk to find the question. The question gets asked and you can either answer it or have it as a basis for team discussions. When that's done, ask another student if he or she has a question. Usually, it's only then that students come to realize that there's a question taped under all the desks. An entire class period can thus be used going over these valuable questions.

Reward Race

A set of not-so-easy multiple choice questions are posted around the room. Students work in teams to answer these questions. The first team to get all answers correct wins the prize, preferably something made of chocolate. Strategies are important. Some teams will decide to split up. Others will stay huddled as they migrate from one question to the next. Also, if a team

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submits answers but gets at least one wrong, they are not allowed to submit answers again until either all the other teams have had a chance or after a specified amount of time. Furthermore, the instructor does not tell teams which questions they got wrong, only the number of them they got wrong. This is certainly one of the more fun activities.

Office Visits

While the class is occupied with some learning activity (pensive activities, such as the Practice Sheets are best), the instructor pulls individual students away for a brief office visit. The instructor inquires about how things are going and whether the student has any general or specific questions or concerns. This is also a good time to show the student his or her present course grade and provide advice on how to do well in the course. Furthermore, this activity serves as an important ice-breaker that makes students more inclined to take advantage of your regular office hours.

Field Trip

Class-size permitting, take students on a tour of the department's teaching and research laboratories. Ask your colleagues whether they would be willing to talk to your students regarding what they like about science and why they chose it as a profession.

Salon de Chemie

Bring in a stack of recent science journals, both popular and technical, and set the classroom up as though it were a coffee house—quiet background music, tea, donuts, etc. Students merely spend the class time reading through these journals and discussing science-related topics with their peers as well as the instructor. Strange but true, many if not most of your students have never read through a science journal or magazine. Perhaps, down the road this activity will help them to think twice about throwing away one of those pervasive science magazine subscription offers.

Salon de Chemie is also a good forum for the Contextual Chemistry essays. Assign each student his or her choice of Contextual Chemistry essay. Students use the class period to read their selected essay while you roam the class answering general and specific questions. Place students in teams in one of two fashions: (1) each student on a team has read the same essay, or

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(2) each student on a team has read a different essay. In the first case, students can discuss the questions at the end of the essay. In the second case, each student can be required to summarize the important points of their essay to the other students.

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Instructor-Centered Learning Activities

(What the instructor can do outside of class)

Class Journal

Student-centered learning is such fertile ground for educational innovation. As soon as possible after class, I encourage you to open up your Class Journal and start recording what went well and what went wrong. I can almost guarantee that through this process ideas for improvements and new ideas altogether will arise. You should document the details of each class session even if you don't think anything unusual occurred. Unbeknownst to you, many ideas are likely brewing within your subconscious. The process of writing in your journal, especially soon after class, is a great way to allow these ideas to bubble up to the surface where you can consider them in fuller detail. Most all of my new curriculum ideas are generated through my own class journal, which is available to you through www.ConceptualChemistry.com.

Think-Pair-Share

Think about your curriculum using your Class Journal. Discuss your experiences and ideas with your colleagues. Then share your ideas with others through departmental seminars or regional or national meetings. The key word here is synergy. We instructors don't work in a vacuum. In working together we can fast-forward to better ways of reaching our non-science oriented students. Today, we find a growing gap between those who embrace science and those who shun science. Our efforts to bring everyone to understand science as a beautiful and effective way of viewing the universe is of utmost importance.

Explore References

Here are a few references that you will find helpful as a starting point for learning more about student-centered learning techniques.

Thomas A. Angelo, K. Patricia Cross, *Classroom Assessment Techniques, A Handbook for College Teachers, 2nd ed.*, Jossey-Bass, 1993.

Eric Mazur, *Peer Instruction: A User's Manual*, Prentice-Hall, 1997.

Jeffrey P. Adams, Timothy F. Slater, *Strategies for Astro 101*, Prentice-Hall, 2003.

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Chemical Concepts Inventory
http://jchemed.chem.wisc.edu/JCEDLib/QBank/collection/CQandChP/CQs/ConceptsInventory/CCIIntro.html

or just type: “Chemical Concepts Inventory” into Google.

Collaborative learning activities
www.wcer.wisc.edu/nise/cl1/cl/

Field-Tested Assessment Guide (CATs)
www.flaguide.org

Just in Time Teaching
www.JiTT.org

Process Oriented Guided Inquiry Learning (POGIL)
www.POGIL.com

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About the Supplements

ConceptualChemistry.com

The Conceptual Chemistry Alive!! (CC Alive!) video lecture series featuring the author's lecture presentations, demonstrations, and more are available to students at ConceptualChemistry.com. Each video lecture averages only 7 minutes in length, but there are more than 200 of them spanning the table of contents of the textbook. These video lessons are best thought of as the "talking textbook" where students get to see and hear the concepts of chemistry. These video lessons complement the textbook as a means of delivering the content of chemistry. This, in turn, supports the instructor seeking to dedicate his or her classes to student-centered learning activities, such as Process Oriented Guided Inquiry Learning (POGIL).

This website is an obvious resource for distance learning chemistry courses. Less obvious, however, is the idea that ConceptualChemistry.com is equally as useful for the traditional on-campus format, especially for large enrollment classes where a student is less likely to get individual attention from the course instructor.

For my own on-campus courses, I stopped dedicating class time to lectures soon after the CCAlive! video lectures were produced. This has been perhaps the best thing I've ever done for my students (and my course evaluations). The key idea is that students can go home for their lectures, but they come to class to study under the expert guidance of their course instructor. My students actually have a handicap in that the person on the CCAlive! video lessons is the same as the one they encounter in class. One of the positive things I've learned about these video lessons is that disagreements arise between myself and the instructor. Students go "Huh? You mean there's more than one way of looking at chemistry?" Stylistically, the answer is yes. In this way students get a stereoscopic view . . . except for my students who still see in mono.

Some students say I go too slowly in the video lessons. I let these students know that they're not expected to watch all the videos. They should watch only the ones that cover topics that are difficult for them, such as, perhaps, electronegativity. For other students, listening to and watching the video lessons reaches them in a way that the textbook never can. This is particularly important for students with learning disabilities.

A popular feature of the CCAlive! video lessons are the "video check" questions

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that appear with each video lesson. These questions are generally non-challenging, so students should not put too much weight on their having answered these questions. That said, students can be assigned to answer these questions as a means of checking on whether they are watching the videos. My own answers to these questions along with summaries of each video lesson as well as many other resources are available to instructors within the instructor-only area of ConceptualChemistry.com. Please contact me directly at John@ConceptualChemistry.com to register for an instructor's account. Once registered, you will have access to this area and be able to keep track of your students' use of this website for assessment purposes.

ConceptualChemistry.com is my own personal project. I am solely responsible for its content and organization and I look forward to its continued development. Your suggestions for improvements are greatly appreciated. Please check it out!

The Activity Manual

In contrast to the minds-on approach of the Practice Pages is the hands-on approach of *Explorations in Conceptual Chemistry: A Student Activity Manual* written by Jeff Paradis of California State University–Sacramento. The activities of this manual are short and relatively easy to set up. They can be scheduled directly into the course syllabus or alternatively pulled together "on the fly" based on student need or interest as the semester progresses. Students can perform these activities during the lab period. Many are also suitable for class, which is a surefire way to maintain student interest. Their primary goal is to allow the student to learn chemistry by doing chemistry.

The Activity Manual is designed to be flexible. However, the following nine activities are considered to be "core concept" activities and they are key to conceptual development. Additional activities can be selected depending on your students' needs and interests.

Activity 1a: Matter is particulate (low-tech evidence)
Activity 2a: The properties of solids, liquids, and gases
Activity 2c: Heat and the motion of submicroscopic particles
Activity 3: Properties of the elements and the periodic table
Activity 4b: The electrons and the shell model

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Activity 5: Conductivity and models of chemical bonding

Activity 6a: Molecules and Lewis dot structures

Activity 8a: An introduction to mixtures and solutions

Activity 9a: An introduction to chemical reactions

The Activity Manual uses a number of student-centered pedagogical approaches. The most common is *guided inquiry*, which is when the instructor provides a problem for investigation, but the student is expected to devise his or her own procedure to solve the problem. Other approaches employed include *structured inquiry* (when the instructor provides both the problem and the procedure), as well as *open inquiry* (when students formulate their own problems and procedures). Collaborative learning, peer teaching, and model-based learning are also important components of this curriculum.

Each activity begins with a list of key concepts, learning objectives, and pre-reading requirements. Students are also given a page of pre-activity problems. These problems tend to be easy but they help to ensure that the student has completed the required reading. Notably, having students come to class prepared cuts down on the need for a pre-lab lecture. The Pre-Activity Problem Set is spot-graded for a small number of points at the start of lab (late students lose these points) and then passed back to the students. This can be done quickly, often before students have settled into their seats.

The class spends the first 5-10 minutes discussing any difficulties with the reading assignment or the Pre-Activity Problem Sets. This is also a good time to address any student misconceptions. Pre-activity lectures, if given at all, tend to be brief with a focus on "big picture" ideas, underlying pedagogy, or possible safety issues. If students are not coming to class prepared, you should consider a pop-quiz to reward students who are prepared and to penalize those who are not. A single pop-quiz is usually sufficient.

With students working in small teams, most activities can be done within 90 minutes. Some activities, however, take 2–3 hours and are completed over two periods. Many of the activities are set up as self-paced stations where students are led by guiding questions to carry out an activity that not only engages them, but encourages *doing with understanding*. When the students are done, a post-activity discussion is crucial for making sure they have all arrived at the same level of understanding. For the more difficult

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activities, class discussions should occur after each part of the activity rather than at the end of the activity. This helps to keep everyone on the same track.

At this point, the students are now ready to apply their understanding to new scenarios in the Post-Activity Problem Set, which is given as homework and is due the following period. Unlike the Pre-Activity Problem Sets and the questions within each activity, the Post-Activity Problem Set is collected and fully graded. This problem set is designed to evaluate student mastery of the testable learning objectives and to provide the student with feedback on questions similar to those they will see on exams and quizzes.

On the following page is a grid showing what sections of *Conceptual Chemistry* students should read prior to performing each activity.

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Activity Guide	Textbook Sections (CC5e)
Unit 1: The particulate nature of matter	
Activity 1a: Matter is particulate (low-tech evidence)	1.1-1.2, 1.5
Activity 1b: Matter is particulate (high-tech evidence)	2.1
Unit 2: Phases, phase changes, and the effect of heat on matter	
Activity 2a: The properties of solids, liquids, and gases	2.4, 2.7
Activity 2b: Understanding atmospheric pressure	2.8
Activity 2c: Heat and the motion of sub-microscopic particles	2.5-2.6
Activity 2d: Absolute zero and the Kelvin temperature scale	2.6
Activity 2e: Exploring the phase changes	2.7, 8.6
Activity 2f: The difference between boiling and evaporation	8.4
Unit 3: An overview of the periodic table	
Activity 3: Properties of the elements and the periodic table	2.2, 3.2, 3.3
Unit 4: The structure of the atom	
Activity 4a: The nucleus, isotopes, and atomic mass	4.3-4.4
Activity 4b: The electrons and the shell model	4.1, 4.5-4.8, 6.1
Unit 5: An introduction to ionic, covalent, and metallic bonding	
Activity 5: Conductivity and models of chemical bonding	3.4, 6.2-6.5
Unit 6: Exploring covalent compounds (molecules)	
Activity 6a: Molecules and Lewis dot structures	6.5
Activity 6b: VSEPR theory and molecular shape	6.6
Activity 6c: Polarity, intermolecular forces, and boiling point	6.7-6.8, 7.1, 7.5
Activity 6d: The amazing properties of water	8.3
Activity 6e: Symbolic representations of molecules	3.4, 12.1-12.3
Activity 6f: An introduction to polymers	12.8-12.9
Unit 7: Exploring ionic compounds (salts)	
Activity 7: Naming ionic compounds	3.5, 6.2, 6.3
Unit 8: Understanding mixtures and solutions	
Activity 8a: An introduction to mixtures and solutions	3.6-3.7, 7.2-7.4
Activity 8b: Exploring acids and bases	10.1-10.6
Activity 8c: Determination of the sugar in soda	7.3, 13.2
Activity 8d: Making water safe to drink	7.6-7.8, 16.1-16.5
Unit 9: Important aspects of chemical reactions	
Activity 9a: An introduction to chemical reactions	3.1, 9.1
Activity 9b: Endothermic and exothermic chemical reactions	9.4
Activity 9c: Determination of the Calories in a peanut	8.5, 9.4
Activity 9d: Kinetics and the rates of reactions	9.6-9.7
Activity 9e: An introduction to electrochemistry	11.1-11.6

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Everything Else (LM, TB, IRC, CP, BB, WebCT)

The remaining Conceptual Chemistry supplements are self-explanatory. This includes the Lab Manual, the Testbank (fixed up by myself and Tracy, my creative wife who has a special talent for thinking up plausible wrong answers!), the Instructor's Resource DVD, the Chemistry Place, and support for BlackBoard and WebCT, and most notably Mastering Chemistry. For this fifth edition, the lab manual was updated with a new lab on Charles' Law. The testbank was streamlined and then beefed up with a healthy dose of low difficulty questions. The Mastering Chemistry site for *Conceptual Chemistry* was also outfitted with new tutorials and, of course, fully correlated to this fifth edition, which was a major undertaking.

A most interesting feature of the Instructor's Resource DVD is that it contains many of the PowerPoint slides and animations that I created for the production of the CCAlive! video lectures. These are made available for you to modify to fit your own needs. Also included are more traditional lecture outline PowerPoints nicely created by Bradley Sieve of Northern Kentucky University, as well as Clicker Response System questions revised by Phil Reedy of Delta College of San Joaquin. Also found on this DVD is the *Conceptual Chemistry 5e* Art Library, the testbank, and other electronic resources.

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Chapter Discussions

In previous editions of the *Conceptual Chemistry* Instructor's Manual I have included an extensive set of chapter discussions containing suggested lecture presentations and demonstrations. Since I've cut back on lecturing, however, my further development of this material has been minimal. Also, about 85 pages in length, these chapter discussions take up a fair amount of print space. That said, the discussions contain a number of valuable ideas that might prove particularly useful for the instructor just starting his or her teaching career or for the seasoned instructor looking to freshen up his or her class presentations. For these reasons, I am no longer including these chapter discussions within this Instructor's Manual. Instead, they can be found within the Instructors area of www.ConceptualChemistry.com as downloadable .pdf files. I offer these plus my online Class Journal in hopes of giving you some further ideas on how to run a student-centered class.

My Class Journal is written much like a blog. The chapter discussions, however, are more thought out, and the following is a representative example:

The Phase of a Material Depends on the Motion of Its Particles

Particles of a solid are fixed and can only vibrate relative to one another (hold your two fists together while giving them a vibrating motion). Particles in a liquid, on the other hand, are able to tumble over one another much like a bunch of marbles in a plastic bag (tumble your fists over each other). Particles in the gaseous phase are moving so rapidly that they separate from one another altogether (rapidly bring your two fists together and bounce them off each other).

Better yet, skip the above and first ask your students to represent a solid with their fists. Kudos to the students who vibrate their fists about a fixed position. Ask them then to use their fists to represent 0°C ice. Most students are initially reluctant to do this, so your added encouragement will be required. Once they are all going on the 0°C ice, ask them to show –10°C ice, then –50°C, –150°C, then –273.15°C ice. Students will soon realize that they should have had their fists vibrating quite rapidly back at 0°C. Work your way back up to 0°C ice and ask them to show 0°C liquid water, 10°C liquid water, 50°C liquid water, 100°C liquid water, followed by 100°C water vapor.

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ASK YOUR NEIGHBOR: Is it possible to add heat to ice without the ice melting? (Yes, because how else can –100°C ice be brought to –50°C ice?)

DEMONSTRATION: To show how gases occupy much more volume than do solids or liquids, crush some dry ice and use a powder funnel to add some to a balloon. Place the expanding balloon in a tub of warm water for a more rapid effect. In talking about phase changes you may find that the water directly beneath the dry-ice-containing balloon has frozen. Be sure to identify the dry-ice as solidified carbon dioxide having nothing in common with water ice except for its solid phase. Note how the dry ice "sublimes" directly from the solid to gaseous phase. Snow does the same thing, especially high on mountain tops where it is sunny and dry.

Fill a punching balloon with little plastic beads. Blow the punching balloon to full size and then holding the balloon firmly with the palms of your hands, shake vigorously. This is certainly a "hands-on" activity as only the person performing the activity can feel the many pulses of beads hitting against your hands. This is nicely analogous to what happens inside the hot-water balloon (or any balloon, actually) as described in the Hands-On Chemistry Activity "Hot-Water Balloon." Pass the balloon around for some student testimonials. Ask for volunteers to explain how the balloon shaking with plastic beads inside is analogous to the hot-water balloon. Confirm their understandings with an explanation of your own.

To help students get a handle on the many terms describing phase changes, consider organizing the terms around a large triangle you draw on the chalkboard, with the word "gas" at the apex and "liquid" and "solid" at the other two corners. Write out the various terms describing phase changes, such as evaporation, along with arrows that run parallel to the edge of the triangle and also point to the phase being formed by that process. The two terms students are most unfamiliar with are *sublimation* and *deposition*, one of which explains why old ice cubes in the freezer are smaller than new ice cubes. Of course, with the advent of the frost-free freezer came the loss of a great example of deposition. An old glass jar of moth balls will have to do.

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Chemistry Concepts Inventory

The following multiple-choice exam is designed to serve as a standardized inventory of student learning over the course of a semester. It should be taken by your students at the beginning of the semester, such as during the first day of class, and then again at the end of the semester, such as the last day of class or along with the final exam. Students naturally feel less intimidated if on the first day they take the exam anonymously. As described earlier, however, it is useful to have students' names so that you can use their results on the Concept Inventory as the basis for team formations. Of course, students shouldn't be graded for their initial performance on this test. Also, it's good not to talk about the exam much so that they easily forget about it. At the end of the semester, you can consider adding the same ten inventory questions as 1 point bonus questions on the final. When it comes to borderline grades, I find it helpful to consider any improvements in student's scores on the inventory.

The questions on this exam were selected from Douglas Mulford's Chemical Concepts Inventory (CCI), which is a set of 22 questions designed to probe for the misconceptions of students taking general chemistry at Purdue University.* This inventory has been used by numerous faculty at other colleges and universities and has thus become a valuable reference point. Notably, students tend to do poorly on this exam, averaging about 45% at the beginning of the semester and about 50% at the end of the semester. The take-home lesson here is the great difficulty we face in trying to lead students away from their well-entrenched misconceptions.

When given Mulford's CCI of 22 questions, liberal arts chemistry students average about 20% at the beginning of the semester and about 35% at the end of the semester. To save time and build an inventory that is more appropriate to the liberal arts chemistry student., the test reproduced here in this instructor's manual consists of only 10 of these 22 questions. For this abbreviated version, students average about 35% at the beginning of the semester and about 45% at the end of the semester. One recent semester I had as high as a 55% average!

Answer Key: 1 d; 2 c; 3 c; 4 b; 5 c; 6 b; 7 a; 8 b; 9 c; 10 b

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* The "Chemical Concepts Inventory" was developed by Doug Mulford for his M.S. thesis (Douglas R. Mulford, M.S. Purdue University, August 1996. An Inventory for Measuring College Students' Level of Misconception in First Semester Chemistry. Major Professor: William R. Robinson). On the web, type in "Chemical Concepts Inventory" into your Internet search engine.

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Chemistry Concepts Inventory ______________________________

Choose the BEST answer to each of the following.

_____ 1. Assume a beaker of pure water has been boiling for 30 minutes. What is in the bubbles in the boiling water?

a. Air.
b. Oxygen gas and hydrogen gas.
c. Oxygen.
d. Water vapor.
e. Heat.

_____ 2. A glass of cold milk sometimes forms a coat of water on the outside of the glass (Often referred to as "sweat"). How does most of the water get there?

a. Water evaporates from the milk and condenses on the outside of the glass.
b. The glass acts like a semi-permeable membrane and allows the water to pass, but not the milk.
c. Water vapor condenses from the air.
d. The coldness causes oxygen and hydrogen from the air to combine on the glass, forming water.

_____ 3. Heat is given off when hydrogen burns in air according to the equation

$$2H_2 + O_2 \rightarrow 2H_2O$$

Which of the following is responsible for the heat?

a. Breaking hydrogen bonds gives off energy.
b. Breaking oxygen bonds gives off energy.
c. Forming hydrogen-oxygen bonds gives off energy.
d. Both (a) and (b) are responsible.
e. (a), (b), and (c) are responsible.

_____ 4. Figure 1 represents a 1.0 L solution of sugar dissolved in water. The dots in the magnification circle represent the sugar molecules. In order to simplify the diagram, the water molecules have not been shown.

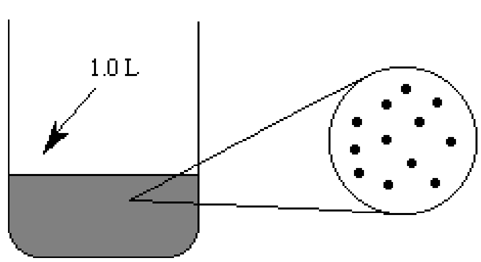

Figure 1

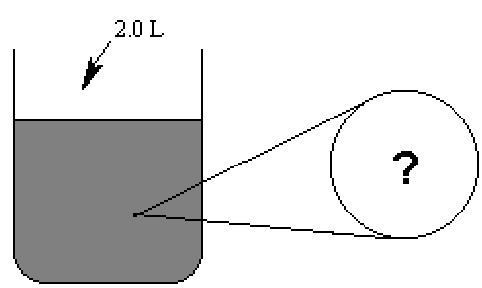

Figure 2

Which response represents the view, as shown in Figure 2, after 1.0 L of water was added?

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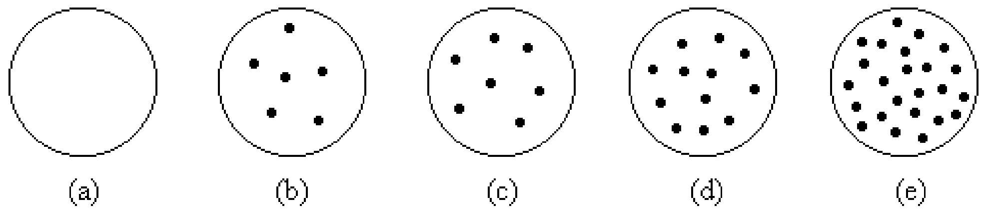
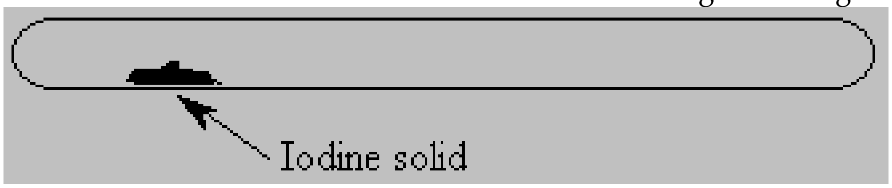


_____ 5. A 1.0-gram sample of solid iodine is placed in a glass tube and the tube is sealed after all of the air is removed. The tube and the solid iodine together weigh 27.0 grams.



The tube is then heated until all of the iodine evaporates and the tube is filled with iodine gas. The weight after heating will be:

a. less than 26.0 grams.
b. 26.0 grams.
c. 27.0 grams.
d. 28.0 grams.
e. more than 28.0 grams.

_____ 6. What is the reason for your answer to question 5?

a. A gas weighs less than a solid.
b. Mass is conserved.
c. Iodine gas is less dense than solid iodine.
d. Gases rise.
e. Iodine gas is lighter than air.

_____ 7. A sample of water (100 mL) and a sample of alcohol (100 mL) at the same temperature (25°C) are both heated at the same rate under identical conditions. After 3 minutes the temperature of the alcohol is 50°C. Two minutes later the temperature of the water is 50°C. Which liquid received more heat as it warmed to 50°C?

a. The water.
b. The alcohol.
c. Both received the same amount of heat.
d. It is impossible to tell from the information given.

_____ 8. What is the reason for your answer to question 7?

a. Water has a higher boiling point than the alcohol.
b. Water takes longer to change its temperature than the alcohol.
c. Both increased their temperatures 25°C.
d. Alcohol has a lower density and vapor pressure.
e. Alcohol has a higher specific heat so it heats faster.

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_____ 9. Iron combines with oxygen and water from the air to form rust. If an iron nail were allowed to rust completely, one should find that the rust weighs:

a. less than the nail it came from.
b. the same as the nail it came from.
c. more than the nail it came from.
d. It is impossible to predict.

_____ 10. What is the reason for your answer to question 9?

a. Rusting makes the nail lighter.
b. Rust contains iron and oxygen.
c. The nail flakes away.
d. The iron from the nail is destroyed.
e. The flaky rust weighs less than iron.

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Suggested Course Syllabi

Conceptual Chemistry has a number of possible "tracks" an instructor might follow in developing a course syllabus. I can suggest at least four different tracks, although your actual path may be a combination of them. These suggested approaches are geared for a semester system. Some ideas on how the approach might be modified for a quarter system are given after each schedule. Within these descriptions you'll find that I refer to the first 12 chapters of the textbook as the "conceptual chapters," while Chapters 13 through 17 are the "topical chapters."

Track 1: Final Project Approach

This is my favorite approach because it takes advantage of the fact that later topical chapters are fairly easy to understand and therefore require of less class time. I try to cover all of the first 12 chapters before the last week of the semester. In the remaining weeks, students select one or more of the topical chapters to specialize in and "learn on their own." They are assessed for their expertise on this chapter on the final exam, but mostly through some end-of-term project, such as the writing of an article or the creation of a poster.

Extensive directions on how to implement a writing assignment are given online in the instructors area of ConceptualChemistry.com. Briefly, students are encouraged to wear the hat of a journalist and write an article similar in form and content to the Contextual Chemistry essays appearing within the textbook. Students peer review each other's work and the best works are then published online at ConceptualChemistry.com.

Another worthwhile end-of-term project is the poster session, which happens on the last day of class. Each student prepares a single poster board designed to communicate some aspect of the chapter material to a general audience. The instructor assigns chapters to students based on student preferences (each student provides their top three choices) while also making sure that there is an even distribution of chapters. It is advisable to alert students to the lengths of Chapters 13 and 14, which can be partitioned based upon student interests. Some students, for example, might be assigned only the later nutrition sections of Chapter 13.

Each student grades all the posters on a scale of 1 to 10 on each of the following categories: clarity of presentation, originality, visual appeal, accuracy, and overall

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impression. They add up their scores for each poster (maximum 50 points). I toss out any scores I think are out of line with the quality of the work and then I find the average score each student received for his or her poster. I also grade for how well each student graded other students, with a maximum of 50 points for well-thought-out critiques. For the entire poster project there are 100 possible points—50 from peers and another 50 for the grading.

You might also ask students about what other sorts of projects they might be interested in doing. For example, one semester my students, working in teams, put together skits to relate the concepts of their assigned chapter. We have also produced Public Service Announcements (PSAs). Students working in small teams write a 2–3 minute script that they read into a voice recorder during class. After all the PSAs are recorded, the voice recorder is plugged into the classroom PA system. Students grade the PSAs during the playback.

Final Project Approach

Week	Subject
Week 1	Chapter 1 About Science
Week 2	Chapter 2 Particles of Matter
Week 3	Chapter 3 Elements of Chemistry
Week 4	*Exam*
Week 5	Chapter 4 Subatomic Particles
Week 6	Chapter 5 The Atomic Nucleus
Week 7	Chapter 6 How Atoms Bond
Week 8	*Exam*
Week 8	Chapter 7 How Molecules Mix
Week 9	Chapter 8 How Water Behaves
Week 10	Chapter 9 How Chemicals React
Week 11	*Exam*
Week 12	Chapter 10 Acids and Bases
Week 13	Chapter 11 Oxidation and Reduction
Week 14	Chapter 12 Organic Compounds
Week 15	Select Topical Chapter and Final Project
	Final Exam (Comprehensive)

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For a quarter system, consider omitting parts or all of Chapters 1, 5, 8, 9, and 11.

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Track 2: Fast Track to Topics Approach

If you want students to spend more time on the topical chapters, omit material within the conceptual chapters. The schedule shown here allows for a minimum coverage of the conceptual chapters and a maximum coverage of the topical chapters. Note that only two mid-term exams are given. Also, consider that the CCAlive! video lectures may be of particular assistance for your students if you need to zip through the basics of the first 12 chapters.

For the topical chapters, consider the “Salon de Chemie” activity described on page 19 of this Instructor’s Manual. Draw a large restaurant setting on the chalkboard and bring in coffee, tea, juice, and Danish (to their surprise!). After a quick quiz, spend the remainder of the class period reading with the students and listening to their quiet science-oriented conversations. You should bring in some relevant science journals -- popular and technical -- or the science section of some well-known newspaper, such as *The New York Times*. It is probable that few of your students have ever taken the opportunity to sit down and read about science-oriented current events, especially from a hard copy journal rather than the web. Salon de Chemie allows you to demonstrate your belief in the importance of reading and there is a valuable synergy that can evolve as students see each other reading. Quiet discussions are to be encouraged. You may be fortunate enough to have an occasional argument. Respectful intellectual discourse is the goal.

Fast-Track to Topics Approach

Week	Subject
Week 1	Chapter 2 Particles of Matter (2.1–2.6)
Week 2	Chapter 3 Elements of Chemistry
Week 3	Chapter 4 Subatomic Particles (4.1–4.4)
Week 4	Chapter 6 How Atoms Bond
Week 5	*Exam*
Week 6	Chapter 7 How Molecules Mix (7.1–7.4)
Week 7	Chapter 9 How Chemicals React (9.1, 9.4)
Week 7	Chapter 10 Acids and Bases (10.1–10.3)
Week 8	Chapter 12 Organic Compounds
Week 9	Chapter 13 Nutrients of Life
Week 10	*Exam*
Week 11	Chapter 14 Medicinal Chemistry
Week 12	Chapter 15 Optimizing Food Production
Week 13	Chapter 16 Protecting Water and Air Resources
Week 14	Chapter 17 Capturing Energy
Week 15	Class Projects

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Final Exam (Comprehensive)

For a quarter system, either omit some of the topical chapters or allow students to choose and study the topical chapters of their choice.

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Track 3: Conceptual-Prep Approach

Conceptual Chemistry has a strong focus on the development of chemistry concepts. This makes it amenable to prep-chem style courses where students are preparing themselves for general chemistry or for various technical fields, such as nursing. The textbook, however, is by intention rather weak in helping students solve math-oriented chemistry problems. Instructors using *Conceptual Chemistry* for their prep-chem courses, therefore, will need to supplement the textbook with their own problem sets, some of which may be based on the Calculation Corners. Problem-solving skills can also be enhanced through prep-chem style laboratories where algebra is frequently employed. A student with weak mathematical skills should be encouraged to co-enroll in an advanced algebra course, especially if he or she is aiming for general chemistry.

Conceptual Prep Approach (Sections devoted to quantitative thinking skills)

Week	Subject
Week 1	Chapter 1 About Science (1.6)
Week 2	Chapter 2 Particles of Matter (2.8)
Week 3	Chapter 3 Elements of Chemistry (3.7)
Week 4	Chapter 4 Subatomic Particles (4.4)
Week 5	*Exam*
Week 6	Chapter 6 How Atoms Bond
Week 7	Chapter 6 How Atoms Bond
Week 8	Chapter 7 How Molecules Mix (7.3)
Week 9	Chapter 8 How Water Behaves (8.5, 8.6)
Week 10	*Exam*
Week 11	Chapter 9 How Chemicals React (9.1–9.4)
Week 12	Chapter 9 How Chemicals React
Week 12	Chapter 10 Acids and Bases (10.3)
Week 13	Chapter 11 Oxidation and Reduction
Week 14	Chapter 12 Organic Compounds
Week 15	*Exam*

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Week 15	Student Projects
	Final Exam (Comprehensive)

For a quarter system, consider giving one fewer mid-term exam and omitting coverage of Chapter 12.

Track 4: Life Science Approach

Many colleges and universities design programs to prepare students to become technicians in areas related to biology, pharmacy, or medicine. The following suggested approach is for a chemistry course enrolling students interested in or destined to enter such programs. This approach also works well for pre-nursing students.

Life Science Approach

Week	Subject
Week 1	Chapter 2 Particles of Matter
Week 2	Chapter 3 Elements of Chemistry
Week 3	Chapter 4 Subatomic Particles
Week 4	Chapter 5 The Atomic Nucleus
Week 5	*Exam*
Week 5	Chapter 6 How Atoms Bond
Week 6	Chapter 7 How Molecules Mix
Week 7	Chapter 9 How Chemicals React
Week 8	Chapter 10 Acids and Bases
Week 9	*Exam*
Week 10	Chapter 12 Organic Compounds
Week 11	Chapter 12 Organic Compounds
Week 12	Chapter 13 Nutrients of Life
Week 13	Chapter 13 Nutrients of Life
Week 14	*Exam*
Week 14	Chapter 14 Medicinal Chemistry
Week 15	Chapter 14 Medicinal Chemistry

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Final Exam (Comprehensive)

For a quarter system consider omitting parts or all of Chapters 5, 7, and 9, and shortening the time spent on Chapters 12 through 14.

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