The Effects of Grouping Students in the High School Science Setting

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The Effects of Grouping Students in the High School Science Setting

Abstract
The objective of this study was to determine if the way students were grouped affected their performance in the classroom. Many studies have focused on grouping or tracking students through various grades based on their ability, while this paper wanted to specifically see how it could affect their performance in a single mixed ability level high school science classroom. Students were separated by three different methods; alphabetical pairings, student choice, and high ability with low ability students; all groups were given the same instruction and observed to see any possible increase or decrease in student performance. Students were compared using their test scores and laboratory experiment reports.

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The Effects of Grouping Students in the High School Science Setting

By

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Submitted in partial fulfillment of the requirements for the degree
M.S. Mathematics, Science and Technology Education

Supervised by

Dr. Diane Barrett and Dr. Bernard Ricca

School of Arts and Sciences
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May 2010
Abstract

The objective of this study was to determine if the way students were grouped affected their performance in the classroom. Many studies have focused on grouping or tracking students through various grades based on their ability, while this paper wanted to specifically see how it could affect their performance in a single mixed ability level high school science classroom. Students were separated by three different methods; alphabetical pairings, student choice, and high ability with low ability students; all groups were given the same instruction and observed to see any possible increase or decrease in student performance. Students were compared using their test scores and laboratory experiment reports.
Dedication

I wanted to dedicate my whole Masters degree and especially my manuscript to my parents, who have taken out loan after loan, and always encouraged me to keep at it. I also wanted to especially thank my girlfriend Jennifer for always being behind me in all my mistakes and successes without ever showing any discontent. She has been a rock for me when it seems she herself was breaking apart. It also must be said that I couldn’t have done this without our cat Mufasa, who always makes me laugh, and sometimes distracted me from working!
Table of Contents

Abstract .................................................................................................................................................................. 2
Dedication ............................................................................................................................................................. 3
List of Figures ......................................................................................................................................................... 6
Review of the Literature ........................................................................................................................................ 8
  Components of Cooperative Learning ................................................................................................................. 9
  The Problem-Solving Experience ....................................................................................................................... 11
  Group Organization ........................................................................................................................................... 13
To Group or Not to Group ...................................................................................................................................... 15
The Advantages of Grouping .............................................................................................................................. 16
The Disadvantages of Grouping .......................................................................................................................... 19
Alternatives to grouping ...................................................................................................................................... 22
Summary ............................................................................................................................................................... 25
Methodology .......................................................................................................................................................... 26
  Participants ......................................................................................................................................................... 27
  Materials .......................................................................................................................................................... 27
  Procedure ........................................................................................................................................................ 28
Results ................................................................................................................................................................. 30
Discussion ............................................................................................................................................................. 36
References ............................................................................................................................................................. 42
Appendix A ........................................................................................................................................................... 47
Appendix B ........................................................................................................................................................... 49
Appendix C ........................................................................................................................................................... 56
Appendix D............................................................................................................................................... 57
Appendix E............................................................................................................................................... 59
Appendix F............................................................................................................................................... 61
Appendix G............................................................................................................................................... 63
List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Comparison of test scores</td>
<td>Pg 34</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Laboratory experiment scores</td>
<td>Pg 35</td>
</tr>
</tbody>
</table>
The Effects of Grouping Students in the High School Science Setting

In this paper, the focus is on the effect of how grouping students effects their ability within the science classroom. The science classroom is an ideal location to perform such a research project because the students need to be placed in groups for most if not all of their laboratory experiments throughout the school year. For the past century there has been an increased amount of attention invested into how students are being grouped in their classrooms, and the effects these groups play on their education (DiMartino & Miles, 2004).

While working in the groups, the students should be able to increase their conceptual knowledge of the curriculum. When students were placed in groups, they were able to ask questions of their classmates, and explain concepts in ways that the teacher could not. This ability to place the knowledge in their own language not only helped the student explaining the work but also to the student that did not understand the concept to begin with.

New York State mandates that a student must have 1,800 minutes of lab time in the classroom in order to take their Regents exam. If each lab is given a time period of sixty minutes, this would amount to thirty labs, or just under one lab per week. While in some subjects, such as Living Environment, there are mandatory experiments, in Chemistry the thirty labs are at the teacher’s discretion. New York State does not mandate how these labs are to be presented. Some school districts will just use a fill in the blank worksheet, while others demand typed formal reports for each experiment.
Effects of Grouping

Review of the Literature

Over the past century there has been over seven hundred research studies conducted on how students are arranged within their classrooms (DiMartino & Miles, 2004). Some call this tracking while others will call it ability grouping. Within any class, whether it is a mainstreamed special education class or a class full of honors and gifted students, there will always be a range of abilities. Ability grouping has been defined as a practice that places students into classrooms or small groups based on an initial measurement of their levels of readiness or capability (Kulik & Kulik, 1992; Neihart, 2007).

When placed in proper groups, it has been suggested that a students’ ability to solve problems and think independently improves. Alternatively though if students are placed in to groups that do not suit their particular needs the students educational progress can suffer. When it is noticed that a student no longer fits into the particular group that they are in, a teacher needs to be able to shift that student into a different group.

In classrooms across the world, students are placed into groups, sometimes these groups are based on their ability within a certain subject, other times they could be formed randomly by a teacher, sometimes students are allowed to pick their own groups. This literature review will cover the many ways in which students are grouped in their classrooms, the many positive and negative effects that tracking provides for students, as well as the impact of different types of grouping within the classroom. It will also be discussed how studies have suggested how to create these different forms of groups.
within the classroom and creating the problem solving expertise needed for all types of learners.

**Components of Cooperative Learning**

There are five main components that should be included when considering whether a teacher wants to create a classroom where cooperative learning becomes a main component of the learning environment. The teacher needs to consider the positive interdependence, face-to-face interactions, individual accountability, interpersonal skills, as well as how well a group can process (Bowen, 2000).

*Positive interdependence.* When working in a group situation, it is best to give an assignment that could not be completed by one person, but needs the cooperation of all the members. This helps create the need for interdependence with the other members of the group. Within the science laboratory setting, the students work in groups where they need to share their resources. Thomas McIntosh (1995) stated that we, as teachers, need to assign the students with the opportunity to solve problems that are realistic to what the students need in life.

*Face-to-face interaction.* Students need to be given time to collaborate within their groups. For an activity to be meaningful and long lasting the students need to be allowed to work together to help fill in gaps that their fellow students may need. Each collaborative group also needs to have face-to-face time with their instructor. The face-to-face time allows the groups time to ask questions and clarify their notions on a particular subject before they start working with an incorrect hypothesis. English speaking students as well as English language learners are equally capable of learning difficult topics and terminology through collaborative inquiry based experiences when
they are allowed the face-to-face time with their instructors (Medina-Jerez, Clark, Medina & Ramirez-Marin, 2007).

**Individual Accountability.** Each student within the groups needs to be held responsible for all information presented and discovered in whatever investigation or problem that they are confronting. While a student may be assigned a particular part of a problem, they need to learn from the other members in their group and be able to execute those parts as if they themselves where the ones assigned to that role. If given an assessment, all students in the group should be able to demonstrate their understanding of all of the components involved (Bowen, 2000; Medina-Jerez, Clark, Medina & Ramirez-Marin, 2007).

**Interpersonal Skills.** When working in collaborative groups students are also given the opportunity to improve their interpersonal skills. When in groups, the students need to be able to communicate not only their roles to the other members of the group, but they also need to be able to ask and answer questions to clarify any concerns that they may have. The students also need to be able to handle constructive criticism based on what they have found out. This is helpful in teaching students life skills because one does not always agree with the people one works with. Grouping allows students a chance to develop trust in new people as well as learning how to handling conflicts when there are disagreements on how to approach a problem.

**Group Processing.** After each group completes the task at hand, they need to be given time to reflect on how their group worked together. They need to be able to discuss what worked well for their group as well as created problems and how these problems could have been prevented or solved in a different way. McIntosh went on to say that
“this type of activity combined with meaningful post-lab discussion about what happened, what thinking processes were used, and what skills the students need to practice is a good way to give students good problem-solving experience” (1995, p. 50).

The Problem-Solving Experience.

According to Bagayoko, Kelley and Hasan (2000), in order to develop the correct problem solving expertise that students need to learn a teacher must concentrate and sustain efforts to develop the following five categories as a base for their learning. The students need to have a solid knowledge base, a skill base, a resource base, a strategy-experience base as well as a behavioral base. Many of these categories commonly overlap and they are in no certain order.

Knowledge Base. If a teacher wants their class to solve any form of problem from significant figures to heat flow diagrams, they must first teach their students the necessary background information. While it is good to revisit topics throughout the school year, it would not be advisable to try to teach World War I every Monday and the American Revolution every Tuesday, instead of teaching them in cohesive units in their chronological order of occurrence. Concise and organized lessons are much different than a set of disjointed lessons with no conceivable connections (Bagayoko, Kelley & Hasan, 2000).

Skill Base. In order for a student to solve a problem the student not only needs the background knowledge, but also the necessary skills to help them solve that particular problem. In a high school geometry class, if a teacher told a student to use the Pythagorean Theorem to solve a problem, it could be assumed that the student would not only know the equation but how to correctly use it. If that same teacher went into a 8x
Effects of Grouping

fourth grade classroom and gave the students the same problem and even told them the equation for the Pythagorean Theorem. These students would be perplexed on how to answer such a question. Just because the students have been told and now know the correct formula, in this case $a^2 + b^2 = c^2$, does not guarantee that the students have learned the proper skills to use such an equation (Bagayoko, Kelley & Hasan, 2000).

Resource Base. A students’ resource base may be very broad. It could include previous knowledge, their notes, textbooks or other references available in their school library and classroom. When in a chemistry classroom, a student would have anything from their textbook to their New York State Physical Setting Chemistry Reference Tables and periodic table. While the students have these resources at their disposal, it does not mean that they will know how to use such resources, this is where the students need to have a previous knowledge on each of the topics. As a student has more resources and learns how to use these resources they are expected to achieve more (Bagayoko, Kelley & Hasan, 2000).

Strategy-Experience Base. Strategy and experience can be explicit to a certain type of problem or it could be transferrable across different mediums. Knowing that a classroom has one foot by one foot tiles on the floor a student may be asked to find the square footage of the classroom. A student with experience in math may just take the dimensions and multiply them to get the area, while a student in the lower grades might actually count each tile. While both strategies would be correct, with experience the older student has learned that to save time you can use your area formula. Learning this formula in a geometry class would prove to be useful in a technical drawing class when a student needs to begin designing a house and placing furniture inside of the different
rooms. Teachers need to be able to build on this base from the first day of class until the last, so that by the end of the week, unit, or even school year, the students in their class have gained experience in answering different categories of questions (Bagayoko, Kelley & Hasan, 2000).

*Behavioral Base.* Behavior is also a major skill to be mastered for students when working in groups, whether the groups are assigned or student picked. All members of a group need to be willing and able to adhere to a previously stated requirement for behavior. If all the students are not able to follow the rules that were set forth, there could be a detriment to one or all of the students learning. When the students are behaving properly, it has been hypothesized that work of a higher quality can be produced. As with the previous categories the students can learn and change their behavior through instruction and practice (Bagayoko, Kelley & Hasan, 2000).

*Group Organization*

Flood, Lapp, Flood and Nagel (1992, p. 610) stated that “groups may vary in terms of why they are established and who they will contain, how large they will be, and what materials will be used, but they should always encourage interactions among students as well as between the teacher and students.” The most suitable alignment pattern for each particular instructional experience can be determined by analyzing each of the student’s strengths and weaknesses. Once this analysis is complete, the teacher needs to be able to match students into groups based on the information the class provided them.

A teacher not only needs to find the correct way to create their groups, but also the correct size for the groups. The size can vary depending on the task at hand. For a
science experiment, students can be grouped in twos or threes. While during a test
review or game, the class could be separated in half to make bigger groups.

In order to ensure a cohesive unit, a shared interest in a certain topic could be a
determining factor in the creation of classrooms groups. While other times whole class
instruction is needed to learn a particular skill related to the upcoming activities. The
knowledge a student holds on the current content or the strategies they possess to
approach a problem can also be used to separate the class. Qin, Johnson and Johnson
(1995, p. 129) stated “In cooperative situations, individuals perceive that they can only
reach their goals if and only if the other group members also do so.” Browne and
Blackburn (1999, p.1107) agreed with Qin, Johnson and Johnson adding that “The
importance and responsibilities of each study group member must be emphasized and
groups encouraged to develop role descriptions for each member.” Each student in the
group needs to know their responsibilities and accept them with eagerness in order for a
successful group to produce the expected outcome.

A teacher can always assign the students into groups based on their work habits as
well. Sometimes a student needs help and will be paired with a student who produces
higher quality. While working on group projects, one would want the students working
and having educational discussions.

Once in the group the teacher can always vary the levels within the group. While
the same information for all groups may be appropriate for some classes, it may not be
appropriate for all classes. While teaching a lesson, a teacher should always be able to
reach the different students at their varying ability levels. A teacher may want to give the
different groups, different levels of similar material. For example, one group could be
working on Ulysses S. Grant’s position on the Civil War while another group could be debating Robert E. Lee’s side.

To Group or Not to Group

It has been argued for years if schools should group their students based on their ability, sometimes called tracking, or not. There have been strong arguments for both the positive and negative effects. Tieso (2003) cites a study that took place in Salt Lake City in 1927, a study was conducted in which an elementary school identified and pre-assessed two equivalent sets of students. The students were separated into one set of homogeneous students, and another set of students were assigned to a mixed-ability classroom. The set of students in the homogeneous classroom ended up scoring approximately two grade levels higher at their end of the year evaluations.

DiMartino and Miles stated “Strategies that promote equity, promote achievement student by student. Strategies that perpetuate inequity promote disillusionment, distrust and disengagement. Heterogeneous grouping and differentiated instruction create an atmosphere of equality and caring in the classroom, and both offer students a better opportunity for success. With each student’s success comes greater success for the teacher, the classroom, and the school” (2004, p. 48). When deciding to form groups in a classroom, the teacher needs to be cognizant of whether or not their students are able to meet two important criteria. “One such condition is that the thinking is distributed among the members of the group. Furthermore, group members are encouraged to share their thinking as they work together” (Palincsar & Herrenkohl, 2002, p. 26).
The Advantages of Grouping

Slavin stated that “cooperative learning has been suggested as the solution for an astonishing array of educational problems: it is often cited as a means of emphasizing thinking skills and increasing higher-order learning; as a means of improving race relations and acceptance of mainstreamed students; and as a way to prepare students for an increasingly collaborative work force” (1991, p. 71). Teacher preparation programs across the country are encouraging prospective teachers to prepare students to become collaborative learners. Preparation for this can range from describing expected behaviors during group work to training and practicing these social skills (Webb, 2009). According to DiMartino and Miles there are three main reasons to track the students within their classrooms. “First it creates greater efficiency and ease for teachers; second, students learn better and feel more positive about themselves; and third, it lessens the sense of failure for slower students” (2004, p. 46).

There have been numerous studies conducted that have acknowledged that students with lower abilities have excelled when grouped with students of superior aptitude (Case, Stevens & Cooper, 2007; DiMartino & Miles, 2004; and Flood, Lapp, Flood & Nagel, 1992). It has also been proven that when students are in groups and need to explain their thinking or positions to other students, that the students are more capable and solidify the knowledge that they have learned (Webb, 2009).

Concurrently a study conducted by Case, Stevens and Cooper (2007) showed that students who participated in a case study of collaborative groups showed an increase in their ability to respond with correct answers from 52.8 percent pretreatment to 63.5 percent post treatment. When compared to the overall population where only 55 percent
of the students were able to respond with correct answers, Case, Stevens and Cooper (2007) showed that by working in cooperative groups the students were able to transfer the progress into their own individual performances in the classroom.

Between 1986 and 1990, Bagayoko, Kelley and Hasan (2000) conducted an investigation where two sections of a general physics college classes where students would attend a two hour session on different ways to solve problems every week. The students who attended the extra problem solving sessions clearly outperformed the others in two ways. “Their averages on the common lecture class exams have consistently been above those of the students in the other problem-solving classes, and 91 percent of the time, one of the students in the problem solving paradigm group has made the highest score on the common exams” (Bagayoko, Kelley & Hasan, 2000, p. 25). As students are placed into groups it has been shown that not only do their scores increase but the dropout rate for female students begins to decrease (Cooper, 1994).

The students attributed the difference in their ability as compared to their classmates to the relatively slower and more in depth problem solving practiced in their extra class. While in these classes, the students were allowed time to engage in a Socratic dialogue, where they were able to discuss the problems and the possible solutions. While holding these discussions the students would be able to make comments at each step of the problem solving process to explain their thought process for attempting their technique for the problem in question (Bagayoko, Kelley & Hasan, 2000).

Browne and Blackburn (1999) carried out a similar experiment with students stating that by using the problem solving approach to learn their laboratory skills, they had a stronger belief in their ability to achieve basic chemistry activities. The students
were also confident that their knowledge of the basic class concepts was superior compared to that of the students who did not participate in the problem solving approach in the laboratory.

These studies showed an increase in their students’ achievement while in the classroom. This increase in student achievement translated to success outside of the classroom as well. When students of limited ability work in groups and see such gains they acquire a more positive outlook on their education. The students start to like high school more and their self esteem begins to increase. Contrarily, Poole (2008) stated that when students are placed into the low ability groups their self esteem actually begins to decrease. All three of these effects change the way the students act while in and think about school (Cooper, 1994; Slavin, 1991).

While in the traditional classroom setting, knowledge is transferred from educator to student via demonstrations, lectures, laboratory experiments and readings (Bransfield, Holt and Nastasi, 2007). One of the main purposes of grouping should be to transfer the responsibility of learning from the teachers to the students so that the students can eventually guide themselves (Ross and Frey, 2009, Flood, Lapp, Flood and Nagel, 1992; Palincsar and Herrenkohl, 2002). “Students started to perceive that they learn more readily and embrace problem solving more readily when working with partners” (Browne and Blackburn, 1999, p. 1106). This would allow the students to talk out their ideas and eventually become advocates for their own education and “succeed in increasing the depth and breadth of student learning to enhance and further their levels of achievement” (Tieso, 2005, p. 65).
In order to show that all students learned the necessary material while in their groups every participant should be held responsible for leading the dialogue when needed to (Palincsar and Herrenkohl, 2002). By leading the discussion, the students show that they were active participants in the discussion and not just an inactive member sitting in the group because they had to. “All cooperative learning methods share the idea that students work together to learn and are responsible for one another’s learning as well as their own” (Slavin, 1991, p. 73).

Students from the high ability grouping have said that when placed into a mixed ability classroom they begin to have a negative feelings about their school experiences because they get bullied and have negative peer attitudes thrust upon them (Hallam and Ireson, 2003). A major advantage of using student groups is that there are times when students do not understand the topics and they just need to hear the information from a different light. “In the process of helping a peer address a confusion in the text, students construct metaphors drawing upon action heroes, computer games, song lyrics, and other contemporary popular media which adults may know very little” (Palincsar and Herrenkohl, 2002, p. 27).

The Disadvantages of Grouping

While there have been multiple studies stating that grouping and tracking is advantageous for students, there is also a faction that believes the opposite to be true, where placing students into ability groups could dishearten students. It has been said that when students are placed into their ability groups they are also placed into an educational hierarchy or caste system (Allington, 1980; DiMartino & Miles, 2004; Flood, Lapp, Flood & Nagel, 1992; Poole, 2008).
Tomlinson (2006) discussed the pedagogy of poverty and the pedagogy of plenty. The pedagogy of poverty says that teachers and society in general expect less from students that come from poverty. These low expectations can prove to be true when the teachers do not challenge the students the same as they would students from a different economic background. When these students are not challenged, they are not expected to learn as much and do not seem to see why they should, which in turn just places them back in to poverty when they leave school (Tomlinson, 2006). The students in the lower level classes are often asked questions where they are not expecting them to use the higher levels of Bloom’s Taxonomy to answer questions (Shake & Allington, 1985). “The students of lower attainment were perceived as more likely to develop low self-esteem, become alienated and as a result exhibit more difficult behavior when they were placed in structured ability groups” (Hallam & Ireson, 2003, p. 354).

Arranging groups.

According to Lamanauskas (2009) it is inappropriate to place students into groups for two reasons. The first reason being that grouping is based on a certain teacher’s approach and evaluation. The second reason is that the quiet student is not always self-sufficient as they frequently submit to the intentions and decisions of other group members. It has also been shown that affluent children are more likely than students from a low socio-economic status homes to be placed in a high ability group, while the economically challenged families have their children placed into the low ability groups. Ethnic minorities seem to be also underrepresented in the higher ability classrooms (Hallam and Ireson, 2007; Neihart, 2007).
Problems in the classroom.

There was strong consensus from educators across different types of educational institutions that there were more obedience problems in the lower ability classrooms when tracking and ability grouping were adopted. It is a common belief that the setting of a classroom could have an impact on the attitude of the students. While students who are placed into the lower ability classrooms have lower self esteem and are less likely to try to enhance their ability to try to move from these low ability classes (Hallam & Ireson, 2003). Contrarily the opposite is also true for the higher ability classrooms (Cooper, 1994; Slavin, 1991).

It is also a concern that there is not a fair allocation of resources and quality instruction for the students who are in the low ability classes. It is thought that these students receive an inferior education because teachers try to educate them in a different way. (Neihart, 2007; Poole, 2008). One way that these students in the lower ability groups receive a lower quality instruction is the amount of time that they spend reading. When they do read, they are often interrupted to be corrected (Poole, 2008).

Contrarily if a teacher is expecting students to succeed and achieve at a higher level, then they will do just that. This is the pedagogy of plenty (Tomlinson, 2006). The problem occurs when teachers who teach what they consider to be the poverty-laden class do not set their expectations at the same level. There have been numerous accounts of teachers who, by setting their standards high were able to get their students to achieve at the levels that no one thought possible.

Ron Clark (Clark, 2003) was able to bring an inner-city class of New York City grade school students to excelling levels. During the 1980’s Jamie Escalante (Musca,
Motion picture, 1988) at Garfield High School in Los Angeles was able to get his entire class of Latino students to achieve a score of a five on their AP Calculus exam. The most recent example was Erin Gruwell (Gruwell, personal communication, July 28, 2005) who was able to get her inner city students to not only come to school, but to enjoy it, and even was able to get a book published by them. While these examples are heartwarming stories, unfortunately they are in the minority. When students are placed into the lower level ability groups, it can create a wider achievement gap between the students in the higher level and lower level groups (Flood, Lapp, Flood and Nagel, 1992; Poole, 2008).

Alternatives to grouping

Most teachers go into the classroom with a plan. A plan, which if followed and executed correctly, will always lead to a successful outcome. Unfortunately, no matter how well planned out something is, there can always be some kind of unknown, something that can alter your approach. Teaching is definitely an example of that, a teacher may teach the same class four times a day, but may need to attack each of those four classes in different ways. Ability grouping and tracking does not always work for all students. No matter the amount of research conducted, there will never be a single way to reach all children; therefore educators need to have some alternatives to work with.

Subject grouping

One alternative to tracking and ability grouping as proposed by Hallam and Ireson (2003) was to place students into mixed ability groupings for specific subjects. “English and humanities were the subjects considered most suitable for mixed-ability teaching. Those considered most unsuitable were mathematics and modern foreign languages” (Hallam and Ireson, 2003, pp. 350-351). This concept allows for students to be ability
grouped in certain subjects and then also placed in mixed ability groups for others. There are some schools in Rochester, New York that are run in this manner where a student can be in an honors class for one subject and a remedial class for another, based on their ability and comprehension for that subject matter.

Mobility in groups

Students groups must be allowed flexibility and provided opportunities for all students to change groups according to their abilities on a specific skill (Neihart, 2007; Slavin, 1991). Flexible grouping has been defined as “grouping students for different purposes with frequent changes in the group membership” (Poole, 2008). This could be achieved multiple ways with in a school. If the class is already a mixed ability classroom, then the students can be prearranged into groups, and during the unit, marking period or school year the students can move up or down to accommodate their skills for the multitude of topics covered with in the school year. It has been stated though that there would be trouble trying to switch ability groups during the school year or unit (Ireson, Clark and Hallam, 2002; Poole, 2008). When surveyed, “a substantial proportion of pupils expressed a wish to change set, most, but not all, in an upward direction, mainly because they level of work was inappropriate” (Hallam and Ireson, 2007, p. 27).

In a study conducted by Hallam and Ireson in the United Kingdom where students were placed in ability groups for grades seven through nine. When the students in the study were asked about their satisfaction with their placement “55 percent of the pupils indicated that they were happy, 26 percent wanted to move to a higher group, 12 percent wanted to be with their friends, two percent to a lower group, and five percent to be with a particular teacher” (Hallam and Ireson, 2007, p. 29).
Peer-led team learning

Peer-led team learning is yet another alternative to ability grouping. In the peer-led team learning a teacher is given students who have already completed the course in which they are teaching with a grade of B or better. These students are trained as peer leaders who guide four to eight students who are in need of help conceptualizing and understanding the process needed to solve problems. The peer leaders are not expected to be teachers, or experts. Rather, they are supposed to be there for the students to ask questions and are then able to get a different point of view for which they can use on the problems. Peer-led team learning has been shown to “increase the percentage of students receiving an A, B, or C grade and decrease the percentage of students who fail relative to the traditional non-peer-led team learning classrooms” (Quitadamo, Brahler, and Crouch, 2009, p. 30).

Watkins and Wentzel (2002) agreed with the peer-led team learning concept. They stated that while forming collaborative partnerships, a preparation program would need to be set up to instruct the peer leaders on how to give constructive positive feedback, explain and elaborate their ideas, as well as engage their charges. These peer tutors also benefited from such interactions by offering the high achieving students the opportunity to learn how to negotiate and successfully interact with diverse populations such as students with special needs or those who demonstrate less social competence (Watkins and Wentzel, 2002; Palincsar and Herrenkohl, 2002). “When using peer-mediation combined with differentiated science activities, students appear to learn more content than when taught more traditionally, without peer-mediated learning activities”
Effects of Grouping


Summary

In some forms of cooperative learning, students work together to complete a single worksheet or to solve one problem together. In such methods, there is little reason for more able students to take time to explain what is going on to their less able group mates or to ask their opinions. When the group task is to do something, rather than to learn something, the participation of less able students may be seen as interference rather than help. It may be easier to in this circumstance for students to give each other answer than to explain concepts or skills to one another. “International research on the effects of ability grouping in schools, although extensive, does not provide unequivocal indications of the relative effectiveness of homogeneous or heterogeneous grouping. Several reviews of research show that the effects of ability grouping are inconsistent, varying across studies, in different countries, over time and between schools” (Ireson, Hallam and Hurley, 2005, p. 444).

In contrast, when the group’s task is to ensure that every group member learns something, it is in the interests of every group member to spend time explaining concepts to his or her group mates. Studies of students’ behaviors within cooperative groups have consistently found that het students who gain most from cooperative work are those who give and receive elaborated explanations. In contrast just giving and receiving answers without explanations were negatively related to achievement gain. What group goals and individual accountability do is to motivate students to give explanations and to take one another’s learning seriously, instead of simply giving answers (Slavin, 1991). The
students are very much aware of the negative connotations associated with being in a low ability group; alternatively, they were also aware of the pressure that comes with being in a high ability group. Students have said that they wanted to change their groups so that they can just be average. This shows that a fair amount of students would care more to just fit in and be accepted by their peers than attain the highest academic levels (Hallam and Ireson, 2007).

Methodology

The purpose of this study was to examine the contribution of student grouping in students’ ability to create grade level appropriate laboratory reports and increase the students test average in the their high school chemistry classroom. Many studies have shown that the use of constructive criticism and continuous feedback to help in the growth of students’ ability. The laboratory reports and test grades of students who were placed in ability based groups were compared to the laboratory reports and test grades of students who were able to pick their own partners for their experiments. The students’ laboratory reports were evaluated based on their growth from the beginning of the school year to the mid-year point, while the test averages were compared across the line. The evaluations between the two groups of students, ability grouped and non-ability grouped were then examined to judge the role of ability grouping in the science classroom.

Student performances in the classes were measured based on two different standards. The first standard to be addressed was the scores from the students’ first semester test compared to their unit six – kinetics and equilibrium test that was taken at the end of the unit of study during the conducted research. The second standard being addressed was the student’s ability to create a proper laboratory report in which they were
able to convey coherently their findings and understandings. In both the first class, as well as the third class, there were an odd number of students. Therefore, the three students in the middle of the alphabet and ability level respectively were matched into a group of three. The term high ability was defined as having mastered the subject area with scores of 85 or better, students labeled low ability were those that had scores below 65 percent.

Participants

The subjects chosen for this study were high school students in a chemistry classroom where the students’ success in previous science classes varied from poor to excellent. The students were drawn from three different classes that were taught by the same teacher, while completing the same tests, notes and laboratory experiments. All sixty two of the participants in the study were in their third year of a high school level science class, although the students ranged from sophomores to seniors in high school.

Four students were listed as special education students with individual education plans (IEPs) and six students were classified with a 504 plan. All of the students’ accommodations were met during the study including extended time, quiet testing area and test read. No student refused any of their modifications.

Materials

Most of the students in this level of high school chemistry have had little experience in the act of writing a full laboratory experiment report. If the students were given a choice between completing a traditional handout, a fill-in-the-blank report or writing out the full laboratory report, students would chose what was familiar to them which was, unfortunately, the handout. When the students were asked why they chose
the handout, they said, it was easier than writing out a report, and that a lot of the students
did not have a computer and or a printer at home.

While in the first week of class the students in each of the three classes were
given a science skills pre-assessment test (Appendix A) in order to gauge their ability,
and where they stood on some basic concepts of chemistry. In this study, students were
given both a laboratory report format guide (Appendix C) as well as a laboratory report
rubric (Appendix D) which explained how the students would be graded on their
laboratory reports.

Procedure

The research was conducted across three high school chemistry classes at a local
suburban high school. Students in each of the three classes were placed with laboratory
partners based on different criteria. The first class was told that their laboratory partner
would be the student that was either directly above them or below them in the
alphabetical roster. The second class was allowed student choice on their partners, with
the stipulation that, whomever they picked was their partner for the entire unit of study.
The final class was grouped based on the students’ ability as determined by the science
skill pre-assessment test given in the first week of school and the chemistry mid-term that
the students took the week before the study began. In the third class the students were
matched so that the highest-ability student was matched with the lowest-ability student,
the second highest-ability student with the second lowest-ability student; and that pattern
continued to the middle.

The first two marking period’s unit tests’ averages were also used as an indicator
to their ability level. The students in these laboratory groups sat together in class, worked
together the entire unit of study on their experiments, and reviewed together for the test. Each student was responsible for handing in his or her own laboratory experiment report for each experiment, although they were always allowed and encouraged to work together with their partner to ensure the best quality experiment and report possible. When in review classes, the partners would work together on a review sheet, and compete with the other groups in the class by trying to get the most number of questions correct on their multiple choice review sheets.

During the first semester of the school year, the students were mainly given handouts with a fill-in-the-blank for their laboratory experiments. Therefore the students early laboratory scores were based out of ten points, five points were awarded for the simple fact of handing in their report, while another five points were awarded based on the responses to the questions placed on their laboratory sheets.

In order to establish a base line for the students’ ability to write a proper laboratory report, all three classes participated in the same laboratory experiment during the second marking period and were required to write up the experiment in a laboratory report. The students were not given a format guide or a rubric to use while writing their reports. This was to try and see what the students considered to be important pieces of information to include. The students were told that another person should be able to pick up their report and conduct the same experiment and get similar results based on their paper. To establish a baseline for the students’ ability in a science class the students were given a basic skills test in the first week of school, which included reading scientific equipment, analyzing data to determine a trend, as well as locating information on the New York State Physical Science/Chemistry Reference Tables.
After the students had their first laboratory experiment report returned to them, they were given some time to look it over and peruse the comments made by the teacher. The students were then given both the laboratory report format guide as well as the laboratory report rubric. Over the next class period the students went over the proper format for creating a laboratory experiment report as a class. The students were then instructed that for each of the remaining laboratory experiments performed in the school year, the students would need to write proper laboratory experiment reports. After each of the experiments, the students were given a week to write up the report and hand it in for grading. The students were given the opportunity to re-write any reports based on the teachers comments for a week from the date the laboratory reports were returned to the students.

For most of the test subjects, the experiment took six weeks to complete, running shorter than the originally planned full semester to full school year that would have been preferred. A single unit is not preferred for this study for a plethora of reasons, mainly is absences. There were couple different students who were absent from school multiple days within the unit. This puts the student behind in a time constrained unit. If the study were to be conducted over the longer time period, this would still be a problem, but it could be neutralized.

Results

The students were not given the laboratory report format (Appendix C) and laboratory experiment report grading criteria (Appendix D) until the beginning of the research unit of study. The students’ laboratory experiment report pre-assessment was taken from their previous unit, unit five, mathematics and stoichiometry, where the
students wrote two complete laboratory experiment reports without the guidance of the teacher, the Laboratory Report Format (Appendix C) or the Laboratory Report Grading Criteria (Appendix D). To assess the students’ growth, the students’ final laboratory assessment was based on their lab on the Rates of Reaction (Appendix E).

In order to use statistical analysis, the average scores for the two groups of students were studied and compared, instead of by an individual student basis. Through the examination of the student data, using the student t-test, it was determined that the averages were sufficient representations of most student scores as they accurately represented the majority of the student score. Since each test was worth between a maximum of forty and fifty points, the scores were converted to a percentage out of a one hundred point scale to make the scoring more universal and easier to compare.

Pre-Assessment

A week after the students completed their Unit five tests on mathematics and stoichiometry, the students took a mid-term examination created by the team of chemistry teachers. The chemistry mid-term (Appendix B) was averaged with the students’ first semester test average and used as the students’ pre-assessment. The mid-term was a two part exam, consisting of fifty multiple choice questions taken from previous New York State Regents exams on day one and eighteen extended response questions worth a total of thirty eight points on day two. These scores were then converted to a more universal one hundred point scale. The average initial scores for the three classes were 72, 72, and 74 respectively.

Each of the three classes were separated based on the methods discussed in the methodology. It should be noted that the third class not only had the highest average
from the combined pre-tests, but it also was comprised of the highest as well as the lowest scores for the pre-tests. In order to pair the students up fairly, the highest ability student, based on the student’s score from the chemistry mid-term examination, was matched with the lowest ability student.

The students did have two full laboratory reports that were completed earlier in the first semester with no guidance on how to create and order the sections of their laboratory report. These laboratory reports as well as the two completed during the research were based on the twenty point scale shown on the laboratory report grading sheet (Appendix D).

*Practice Data*

Students in each of the three classes were given the same instruction from the teacher as well as practice problems and homework assignments to complete. A consistent percentage of students from each class completed the required practice problems during the unit of study, kinetics and equilibrium. Students were not graded on the accuracy of their practice problems but instead on the completion. Each assignment was based on two points for a full completion of the homework with partial credit assigned if the students completed only part of the homework.

All students were given a guide by the teacher on the correct way to create a laboratory report (Appendix C), as well as the criteria by which those reports were to be evaluated by the teaching staff (Appendix D). There were two different laboratory experiments during the kinetics and equilibrium unit of study: Rates of Reactions lab (Appendix E) and Observations of an Equilibrium System lab (Appendix F). During the first laboratory report on the Observations of an Equilibrium System, the students wrote up their laboratory report with their partner, each handing in their own, but the students
were able to use the laboratory report grading criteria (Appendix D) as a reference. The students were given their laboratory reports back in class, and were given a week to correct and re-submit any mistakes that were made.

*Unit Test*

After completing the practice packet, both laboratory experiments, and a whiteboard review session, students from all three classes were given the unit of study, unit six, kinetics and equilibrium unit test (Appendix G). The unit test consisted of thirty multiple choice questions and nine short answer part two questions.

Although all three classes took the same two pre-assessments, there was only one class broken up based solely upon their ability levels. That third class was chosen to be broken up based on their ability level because this class not only had the highest overall average on the combined classroom pre-assessments, but also had both the highest performing student as well as the lowest performing student.

As can be seen from figure 1, all three classes showed an increase in scores from the students’ chemistry mid-term examination to the unit of study, unit six test. This increase of scores were determined to be significant according to the students’ t-test for both the alphabetically paired and ability level paired class. Although there was an increase in the student choice class, it was not determined to be significant by the same students’ t-test. When the scores from the unit of study, unit six exam were compared to the students first semester test average, all three classes were determined to be significant. Unfortunately, the alphabetically paired, and student choice classes were shown to be significant in a negative direction, while the class separated by ability level were shown a positive significance in their score change.
When the student’s chemistry mid-term examination scores were averaged with their first semester test scores, it can be seen that the class that was separated based on their ability level showed a significant increase in score, a jump of eight percentage points. While the other two classes showed no significant change. Students from the alphabetically separated class increased their score by an average of one and two-thirds percentage points; the students in the student choice class improved their score also, but only buy two-thirds of a point; while the class matched by their ability level raised their test scores by an average of almost eight points each, with the biggest increase being thirty four points.

Figure 1. Comparison of Test Scores.
Laboratory Experiment Reports.

As shown in figure 2, all three classes showed an increase in their laboratory experiment report scores. This increase could be attributed to the fact that the students were given the laboratory report grading sheet. Each class showed an increase of a minimum of fifteen percent in their average laboratory experiment report score from earlier in the school year. According to the students’ t-test, all three classes showed a significant change. The class separated by ability level showed the greatest improvement as well as the highest overall score. This could be attributed to the fact that the class matched by ability level, had lab partners’ work on the reports together, and the student in the higher ability category would pressure their partner to excel.

Figure 2. Laboratory experiments scores.
Discussion

The results presented are slightly skewed because of the shortened research period allowed by the time constraints. Despite the daily instruction emphasizing the importance of working together with their partners to enrich their learning and increasing their ability to complete full laboratory reports, a majority of the students failed to increase their test scores.

Each of the three classes was compared on three different bases. Their unit of study, unit six exam score was compared to their chemistry mid-term, their first semester test average, and also the average of their chemistry mid-term and first semester test average. The thought process behind this was to see if there was a consistency throughout the year or if the chemistry mid-term was overwhelming to the students.

The first class, which was separated by their place in the alphabet showed a significant decrease from their first semester test average score. The scores decrease from an eighty percent to a seventy four percent. The students attributed this to the fact that they thought they were having their privileges revoked by being placed into the seats they had at the beginning of the year. While when the students unit six test scores were compared to their chemistry mid-term scores, there was a significant increase in their scores. The average mid-term score for the first class was sixty five percent, by increasing their score by nine points, the students showed a significant increase. If the average test score from the first semester was averaged with the mid-term score, there was no significant change in score as the unit six score was only two percentage points higher.
The students in the second class were by far the most off-task of the three classes. By allowing the students to pick their own seats, they did not make wise decisions to sit next to someone that could help them achieve what they needed, but instead chose to sit next to their friends where they decided to talk more often. The fact that this class was backed by a homeroom period originally was thought to help the process, since they would have an extra twenty minutes of class time if needed, when in actuality it hindered the process by making the students want to end class earlier so that they could just get up and move around and talk. Students were also allowed to pick their own seats, which meant that there would be empty science desks in front of some groups, as the students wanted to sit in the back of the room instead of up near the whiteboard, creating some problems with the students’ eye sights.

When the students from the class where the students were able to choose their own partners first semester test average were compared to their unit six test there was a significant decrease in the score. Their first semester test average was seventy seven percent and the unit six test average decreased by five points to seventy two. Although the students average increased six points from the chemistry mid-term to the unit six test, according to the students’ t-test was not shown to be significant. When the unit six test was compared to the average of the mid-term and first semester test average, there was no change, both receiving an average of seventy two percent.

In all three comparisons the class matched by ability level showed a significant increase in their test scores according to the students’ t-tests. According to the student’s t-test performed this increase of student test scores for the third class where the students were paired up by the teacher so that the high achievers were partnered with the low
achievers were significant and can most likely be accounted for by the students at the upper end of the ability scale not wanting their scores to drop. Those upper achieving students originally assumed that their grades would be affected, albeit indirectly, by their partners’ performance. When asked, the upper level students thought that being paired with a student of lower ability would decrease their score. During the unit of practice though there was a noticeable change in the behavior and approach that the lower ability students had towards the class during this unit of study. These students in the lower ability spectrum spent less time talking and more time taking notes and asking questions, they were even able to help the higher achieving students with some of the difficult concepts.

These lower ability students were more likely to come to the after school and Saturday help sessions during this unit of study also. In addition there was a decrease in the number of behavioral problems and outbursts when the lower achieving students, who normally were the students creating the outbursts, were paired with the higher achieving students and not allowed to sit with their preferred friends. This could be attributed to the pressure exerted on them by their highly motivated higher ability partner to not change their set routine which has allowed them to become the high achieving students that they are.

When the students of the three classes were asked what they thought of the pairings at the beginning of the unit, there was some hesitation from both the high achieving and the low achieving students. The high achieving students were afraid to see their scores be affected by being forced to work with other students, while some of the low achieving students did not like the idea of being placed into a group with someone
that they did not know or get along with. After the unit of study, the students were again asked what they thought of the pairings. The low achieving students came out with positive remarks, saying that they like how they could talk over a concept with their partner, and have them explain it to them in a different way that made more sense. They also said it helped having a partner to study with. The high ability students also came out of the study with a positive outlook, not only were they happy to make new friends, they learned that these low ability students were not as dumb as they originally thought they were, they just had different problems to deal with outside of school.

The opposite effect could be seen in the first two classes where the students were placed into their groups alphabetically and where the students were able to choose their own partners. When the students were placed in their groups alphabetically, the students believed they were being punished, and losing privileges, because that was the seats they had at the beginning of the school year. In their eyes this meant that they had done something wrong, which made the class slightly combative.

While chemistry is considered a third year science at this particular school, many of the students in the third class were only sophomores, which made the chemistry classroom in essence an honors class for them. The first two classes were made up of largely juniors and seniors; one might believe a senior to be more motivated than a sophomore. When a senior is taking a class that they need to graduate, they tend to be more pro-active with their approach to the class in seeking help and asking questions. While a sophomore taking a third level class sometimes sees themselves as advanced and doesn’t worry as much because if they fail, they have two more years to make up the class if need be.
There were a number of low scores on the chemistry mid-term exam; this can be attributed to the fact that it was a cumulative exam. Many of the students did not believe that the mid-term examination would not be hard. Since the chemistry mid-term examination was used as part of the pre-assessment, many, but not all of the low achieving students were students that struggled academically in the course earlier in the school year before this study took place, and this left a precedent in them believing that they could not achieve in chemistry. There were a small number of students who were not included in the study, because they either transferred out of the class, out of the school, or dropped out of school, which unfortunately is something that could happen to students when they reach that age and are not enjoying school or achieving in their classrooms.

If this experiment were to be repeated, the time constraint of only one unit would have to be addressed. In order to correctly perform this type of research, the person conducting the research should be allowed to have a minimum of two-ten week periods, or two marking periods, preferable consecutive and at the beginning of the school year and up to a full school year. Some students are more adapt to different units of chemistry throughout the school year. Therefore it would be better to make this study a full semester at a minimum, to see if the pairings did in fact make a difference. It would also be useful to do it at the beginning of the school year so that there are no previous experiences for which the students to compare their struggles with. Another reason it would be good to conduct this study at the beginning of the year is that some of the scores could have been lower for the unit six test scores is because a lot of the work in the
chemistry classroom is cumulative and builds on it. If a student struggles early in the year, they need to find a way to recover in order to succeed in the class.

In this particular classroom where the research took place the students were allowed to sit wherever they wanted for the first two marking periods of the school year as well as work with whomever they wanted to on their homework, group projects, laboratory experiments and reports. Furthermore many of the students felt pressured to create a perfect laboratory report within a single unit of study without having seen any model laboratory reports in the past; therefore it would also be recommended that a folder or binder of example reports be shown at the beginning of the school year so that the students would be able to see the standard to which they will be held.

Just as it is considered in bad taste to recommend a student for a specific class for the following school year in October, it is also not a good indicator of how a student will react to a certain subject as the school year progress, and just by having the students take a pre-assessment at the beginning of the year. Just as Neihart (2007), Poole (2008) and Slavin (1991) have stated, students need to be allowed mobility to move around and change their groups. The groups should be re-arranged periodically, albeit, after every other test, or once a marking period. It is usually commonly known who the smartest student in any class is; therefore, the students should not know that the teacher is placing the best student with the worst student. This could be replaced by alternating how the students are paired as long as it is still someone from the top half of the class with someone from the bottom half of the class.
References


Gruwell, E. (personal communication, July 28, 2005)


1) Define in your own words, hypothesis: ______________________________________
________________________________________________________________________

2) What are the base units for:
   Mass _______     Temperature ____ or _____     Volume _____

3) Convert the following units:
   15 mg = _____ dag      0.00384 kL = _____ cL      32.097 km = ______ mm

4) How many significant figures does each of the following numbers have?
   ____ 0.00684       ____ 32597.0       ____ 1.006 x 10^5       ____ 103000

Use the New York State Reference Tables for Physical Setting/Chemistry to answer the
following questions.

5) What is the title to Table N: ____________________________

6) What does a negative □H represent in Table I? ____________________________

7) What is standard pressure in kilopascals? ______________

8) Give the correct names for the following elements:
   Xe ___________  Ge ___________  Hg ___________
   Ag ___________  C ___________  W ___________

9) What is the symbol for a proton? (Hint: Two possible answers) _________

10) Based on Table J, list the following elements based on their reactivity from least to
greatest
   Al ____  Cu ____  Ca ____  Li ____  Ti ____

11) What is the name of the following polyatomic ions:
    Cr_2O_7^{2-} _______________     HCO_3^- _______________
    H_2O^+ _______________     PO_4^{3-} _______________

12) Based on Table G, what is the most soluble at 50 °C:
    KClO_3  NaCl  KNO_3  NH_3
13) What is the half life of each of the following:

- Radium-226
- Cesium-137
- Francium-220

14) What is the general formula for an alkene?

- 

15) What does the functional group of an organic acid look like?

16) What is the electron configuration of element number 35?

- 

17) What is the melting point, boiling point, and electronegativity of the following elements

<table>
<thead>
<tr>
<th>Melting Pt</th>
<th>Boiling Pt</th>
<th>Electronegativity</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Na</td>
<td>_______</td>
<td>_______</td>
</tr>
<tr>
<td>- Zirconium</td>
<td>_______</td>
<td>_______</td>
</tr>
<tr>
<td>- Element #85</td>
<td>_______</td>
<td>_______</td>
</tr>
</tbody>
</table>

Read the following measurements correctly:

18) 

**Answer**
**Answer**
**Answer**
**Answer**
### Appendix B

**REGENTS CHEMISTRY MIDTERM**

1. Which particle has approximately the same mass as a proton?
   - (1) alpha
   - (2) beta
   - (3) electron
   - (4) neutron

2. An experiment in which alpha particles were used to bombard thin sheets of gold foil led to the conclusion that an atom is composed mostly of
   - (1) empty space and has a small, negatively charged nucleus
   - (2) empty space and has a small, positively charged nucleus
   - (3) a large, dense, positively charged nucleus
   - (4) a large, dense, negatively charged nucleus

3. What is the nuclear charge of an iron atom?
   - (1) +26
   - (2) +30
   - (3) +56
   - (4) +82

4. What is the structure of a krypton-85 atom?
   - (1) 49 electrons, 49 protons, and 85 neutrons
   - (2) 49 electrons, 49 protons, and 49 neutrons
   - (3) 36 electrons, 36 protons, and 85 neutrons
   - (4) 36 electrons, 36 protons, and 49 neutrons

5. Which pair of atoms are isotopes of element X?
   - (1) $^{24}_{12}$X and $^{25}_{12}$X
   - (2) $^{31}_{14}$X and $^{32}_{14}$X
   - (3) $^{13}_{6}$X and $^{15}_{6}$X
   - (4) $^{90}_{40}$X and $^{92}_{40}$X

6. Which electron configuration is possible for a nitrogen atom in the excited state?
   - (1) 2-5
   - (2) 2-6
   - (3) 2-6
   - (4) 2-4

7. The characteristic bright-line spectrum of an element is produced when electrons
   - (1) absorb energy and return to lower energy levels
   - (2) absorb energy and move to higher energy levels
   - (3) release energy and return to lower energy levels
   - (4) release energy and move to higher energy levels

8. What is the mass number of an atom that consists of
   - (1) 20 protons, 20 neutrons, and 18 electrons?
   - (2) 20
   - (3) 38
   - (4) 40

9. The correct electron configuration of the O$^{2-}$ ion is
   - (1) 2-4
   - (2) 2-5
   - (3) 2-7
   - (4) 2-8

10. What happens when two oxygen atoms combine to form a molecule of oxygen?
    - (1) Chemical bonds are broken and energy is absorbed.
    - (2) Chemical bonds are broken and energy is released.
    - (3) Chemical bonds are formed and energy is absorbed.
    - (4) Chemical bonds are formed and energy is released.

11. Which compound would have the greatest degree of ionic character?
    - (1) Na$_2$O
    - (2) H$_2$O
    - (3) CO$_2$
    - (4) NO$_2$

12. Which element forms a diatomic molecule containing a triple covalent bond?
    - (1) H$_2$
    - (2) Cl$_2$
    - (3) N$_2$
    - (4) O$_3$

13. Which compound do atoms form bonds by sharing electrons?
    - (1) H$_2$O
    - (2) Na$_2$O
    - (3) CaO
    - (4) MgO

14. Which type of substance is soft, has a low melting point, and is a poor conductor of heat and electricity?
    - (1) network solid
    - (2) molecular solid
    - (3) metallic solid
    - (4) ionic solid

15. Hydrogen bonds are strongest between molecules of
    - (1) HF
    - (2) HCl
    - (3) HBr
    - (4) HI

16. At room temperature, F$_2$ is a gas and I$_2$ is a solid. The phase difference of these Group 17 elements is primarily due to stronger
    - (1) van der Waals forces between F$_2$ molecules
    - (2) van der Waals forces between I$_2$ molecules
    - (3) hydrogen bonds between F$_2$ molecules
    - (4) hydrogen bonds between I$_2$ molecules

17. The correct formula for lead (IV) oxide is
    - (1) PbO
    - (2) Pb$_2$O
    - (3) PbO$_2$
    - (4) Pb$_3$O$_4$

18. Which compound contains only two elements?
    - (1) sodium chloride
    - (2) silver nitrate
    - (3) potassium chloride
    - (4) ammonium sulfide
10. Which formula below is an empirical formula?
   (1) H₂O₂
   (2) NH₃
   (3) C₂H₆
   (4) H₂SO₄

20. Given the unbalanced equation:
   \[ \text{Na} \rightarrow \text{H}_2 \text{O} \rightarrow \text{H}_2 \text{Cl}_2 \text{NaOH} \]
   When the equation is correctly balanced using the smallest whole-number coefficients, the coefficient for H₂O is
   (1) 1
   (2) 2
   (3) 3
   (4) 4

21. What type of reaction is shown above?
   (1) synthesis
   (2) decomposition
   (3) single replacement
   (4) double replacement

22. Which element has properties of electrical conductivity and luster and exists as a liquid at STP?
   (1) Hg
   (2) Br
   (3) C
   (4) I

23. Properties of nonmetal atoms include
   (1) low ionization energy and low electronegativity
   (2) high ionization energy and high electronegativity
   (3) high ionization energy and low electronegativity
   (4) low ionization energy and high electronegativity

24. Which element in Period 3 has both metallic and nonmetallic properties?
   (1) Na
   (2) Mg
   (3) Si
   (4) Ar

25. Which substance at STP exists in the form of a monatomic gas?
   (1) neon
   (2) oxygen
   (3) chlorine
   (4) nitrogen

26. Bromine has chemical properties most similar to
   (1) fluorine
   (2) potassium
   (3) krypton
   (4) mercury

27. Which is the atomic number of an atom with six valence electrons?
   (1) 6
   (2) 8
   (3) 10
   (4) 12

28. Which aqueous salt solution has a color?
   (1) BaSO₄(aq)
   (2) CuSO₄(aq)
   (3) SrSO₄(aq)
   (4) MgSO₄(aq)

29. Which group in the Periodic Table contains elements that are all gases at STP?
   (1) 11
   (2) 17
   (3) 12
   (4) 18

30. If the elements are considered from top to bottom in Group 17, the number of electrons in the outermost shell will
   (1) decrease
   (3) remain the same
   (2) increase

31. Atoms of which element have the weakest attraction for electrons?
   (1) Na
   (2) P
   (3) Si
   (4) S

32. Based on Reference Table G, which of the following substances is most soluble at 50°C?
   (1) KCIO₃
   (2) NH₃
   (3) NaCl
   (4) NH₄Cl

33. According to Reference Table G, approximately how many grams of KCIO₃ are needed to saturate 100 grams of H₂O at 40°C?
   (1) 6
   (2) 16
   (3) 38
   (4) 47

34. Based on Reference Table G, which salt is least soluble?
   (1) FeCO₃
   (2) Na₂CO₃
   (3) BaCl₂
   (4) CaCl₂

35. The compound whose molecules have the highest average kinetic energy is
   (1) NO(g) at 25°C
   (2) N₂O(g) at 15°C
   (3) NO₂(g) at 30°C
   (4) N₂O₃(g) at 20°C

36. Which temperature is equal to -20 K?
   (1) -253°C
   (2) -293°C
   (3) -235°C
   (4) -293°C

37. Which phase change is exothermic?
   (1) H₂O(s) → H₂O(l)
   (2) H₂O(l) → H₂O(g)
   (3) H₂O(s) → H₂O(g)
   (4) H₂O(l) → H₂O(g)
38. A gas has a pressure of 120 kPa, a temperature of 400 K, and a volume of 50.0 milliliters. What volume will the gas have at a pressure of 60 kPa and a temperature of 200 K?
   (1) 12.5 ml  (2) 50.0 ml  (3) 100. ml  (4) 200. ml

39. Gas samples A, B, and C are contained in a system at STP. The partial pressure of sample A is 38.0 kPa and the partial pressure of sample B is 19.0 kPa. What is the partial pressure of sample C?
   (1) 19.0 kPa  (2) 38.0 kPa  (3) 44.3 kPa  (4) 63.3 kPa

40. How many grams of water will absorb a total of 2520 joules of energy when the temperature of the water changes from 10.0°C to 30.0°C?
   (1) 100 g  (2) 200 g  (3) 30.0 g  (4) 60.0 g

41. Which equation represents the phase change called sublimation?
   (1) CO₂(s) → CO₂(g)
   (2) H₂O(s) → H₂O(l)
   (3) H₂O(l) → H₂O(g)
   (4) NaCl(s) → NaCl(l)

42. Which represents a homogeneous mixture?
   (1) CuSO₄(s)
   (2) Br₂(l)
   (3) NaCl(aq)
   (4) CO₂(g)

43. What is the total number of kilojoules required to boil 100 grams of water at 100°C and 1 atmosphere? [Refer to Reference Table A.]
   (1) 22.6 kJ  (2) 23.4 kJ  (3) 226 kJ  (4) 334 kJ

44. When the temperature of a sample of water is changed from 45°C to 70°C, the change in its vapor pressure is
   (1) 1.0 kPa  (2) 20. kPa  (3) 25 kPa  (4) 101.3 kPa

45. Which substance can not be decomposed into simpler substances?
   (1) ammonia  (2) aluminum  (3) methane  (4) methanol

46. What is the total number of atoms of oxygen in the formula Al₂(CIO₃)₃ • 6H₂O?
   (1) 6  (2) 9  (3) 10  (4) 15

47. The graph below represents the relationship between temperature and time for a substance that was heated uniformly starting at tₒ. The substance was in the solid phase at tₒ.
   During which time interval does the heat absorbed by the substance represent the heat of fusion of the substance?
   (1) tₒ to t₁  (2) t₁ to t₂  (3) t₂ to t₃  (4) t₃ to t₄

48. The approximate percent by mass of potassium in KHCO₃ is
   (1) 19%  (2) 24%  (3) 39%  (4) 61%

49. Using atomic masses given in the Reference Tables for Chemistry, the molecular mass for O₂(g) is 32.0. By experiment a student measured the mass of O₂(g) to be 38.0. What is the percent error in the student’s result?
   (1) 1.25%  (2) 1.43%  (3) 12.5%  (4) 14.3%

50. Cu(s) + 2HCl(aq) → CuCl₂(aq) + H₂(g)
    What type of reaction is shown above?
    (1) synthesis  (2) decomposition  (3) single replacement  (4) double replacement
Base your answers to questions 1 and 2 on the information below.

Potassium ions are essential to human health. The movement of dissolved potassium ions, K⁺(aq), in and out of a nerve cell allows that cell to transmit an electrical impulse.

1. What is the total number of electrons in a potassium ion?

2. Explain, in terms of atomic structure, why a potassium ion is smaller than a potassium atom.

3. Base your answer to the following question on the balanced equation below.

\[ 2\text{Na}(s) + \text{Cl}_2 \rightarrow 2\text{NaCl}(s) \]

Explain, in terms of electrons, why the bonding in NaCl is ionic.

4. Show a correct numerical setup for determining how many liters of a 1.2 M solution can be prepared with 0.50 mole of C₆H₁₂O₆.

5. a Draw two different compounds, one in each box, using the representations for atoms of element X and element Z given below.

Atom of element X = \( \bullet \)
Atom of element Z = \( \circ \)

b Draw a mixture of these two compounds.

6. In the space provided in your answer booklet, show a correct numerical setup for calculating the average atomic mass of carbon.

7. Describe, in terms of subatomic particles found in the nucleus, one difference between the nuclei of carbon-12 atoms and the nuclei of carbon-13 atoms. The response must include both isotopes.
Base your answers to questions 8 through 10 on the information below.

A safe level of fluoride ions is added to many public drinking water supplies. Fluoride ions have been found to help prevent tooth decay. Another common source of fluoride ions is toothpaste. One of the fluoride compounds used in toothpaste is tin (II) fluoride.

A town located downstream from a chemical plant was concerned about fluoride ions from the plant leaking into its drinking water. According to the Environmental Protection Agency, the fluoride ion concentration in drinking water cannot exceed 4 ppm. The town hired a chemist to analyze its water. The chemist determined that a 175-gram sample of the town’s water contains 0.000 250 grams of fluoride ions.

8. Draw a Lewis electron-dot diagram for a fluoride ion.

9. What is the chemical formula for tin (II) fluoride?

10. How many parts per million of fluoride ions are present in the analyzed sample? Is the town’s drinking water safe to drink? Support your decision using information in the passage and your calculated fluoride level.
11. In a laboratory experiment, a student determined the mass of the product, HgBr(s), to be 98.7 grams.
   
   a) Calculate the gram formula mass of HgBr(s). Round atomic masses from the Periodic Table to the nearest tenth. [Show all work. Indicate the correct answer in proper significant figures and include an appropriate unit.]
   
   b) Calculate the number of moles of HgBr(s) produced. [Show all work. Indicate the correct answer in proper significant figures.]

12. Base your answers to the questions below on the following information:

   Ethene reacts with oxygen in a combustion reaction as shown by the chemical equation below:

   \[ \text{C}_2\text{H}_4 + \_ \text{O}_2 \rightarrow 2 \text{ CO}_2 + 2 \text{ H}_2\text{O} + \text{Heat} \]

   a) In order for the equation to be balanced, what coefficient should the oxygen have?
   
   b) What is the mole ratio of ethene to water?
   
   c) How many moles of oxygen are needed if 2.5 moles of ethene are combusted?

13. Four identical balloons contain equal volumes of gas at STP:

   Balloon #1 contains H\textsubscript{2} gas
   Balloon #2 contains He gas
   Balloon #3 contains O\textsubscript{2} gas
   Balloon #4 contains N\textsubscript{2} gas

   a) Which balloon, if any would weigh the most? Explain.
   
   b) According to the Kinetic Molecular Theory, why would the balloons expand if they were heated?

14. Using a triple beam balance and a graduated cylinder, a student collected data on a sample of an element:

   \[
   \begin{array}{|c|c|}
   \hline
   \text{Mass of sample} & 10.9 \text{ g} \\
   \text{Volume of water} & 30.0 \text{ ml} \\
   \text{Volume of water and sample} & 34.0 \text{ ml} \\
   \hline
   \end{array}
   \]

   a) Calculate the density of the sample. Show all work and use significant figures and units.
   
   b) Based on Reference Table S, what element might the sample be?
Base your answers to questions 16 and 17 on the information and the bright-line spectra represented below.

Many advertising signs depend on the production of light emissions from gas-filled glass tubes that are subjected to a high-voltage source. When light emissions are passed through a spectroscope, bright-line spectra are produced.

<table>
<thead>
<tr>
<th>Gas</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown mixture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

16. Identify the two gases in the unknown mixture.

17. Explain the production of an emission spectrum in terms of the energy states of an electron.

18. Fluorine is a Group 17 element. Fluorine is the most electronegative and reactive of all elements. It is a pale yellow, corrosive gas, which reacts with practically all organic and inorganic substances.

a. Draw the Lewis electron-dot structure for an atom of fluorine.

b. What is the definition (or your interpretation) of the term "electronegativity"?

c. Explain why the electronegativity of elements in Group 17 decreases as you go down within that group.
Appendix C

Lab Report Format

Title: Use my title or your own. Be sure the title reflects the subject of the lab.

Objective: What is the purpose of this lab?  
What question is this lab designed to answer?  
What is your hypothesis? (I think ____ will _______ because _____) 

Materials: List like the this materials please.

Procedure: 
1. List the steps from beginning to end. Number each step. 
2. Use complete sentences and pictures (if necessary). 
3. Write between 5 and 10 steps. 
4. Write clearly so that anyone can repeat the procedure. 
5. Do NOT include “get materials” or “clean up.” 

Data and Observations: 
Use tables, charts, and graphs to show your data.  
Use a computer, straight edge, or ruler to make charts and graphs. 
Draw pictures neatly and in color if possible. 
Show ALL calculations and formulas. 
Record answers with significant figures and with correct units. 
Label all pictures, charts, graphs, etc.

Analysis: 
Write the following in complete sentences and paragraphs-
  a. Restate the objective. (“The purpose of this lab was to…”)
     Describe any new skills or vocabulary you learned in this lab.
     Identify the independent and dependent variable. 
     Discuss the controlled variables or control group in the lab.
  
b. Discuss how your data does /does not support your hypothesis. 
     Explain WHY your data turned out like it did. 
     (i.e. discuss the concept that explains your results) 
     Explain any sources of error or ways to improve the experiment.

Conclusion: 
Discuss one major concept or theme of chemistry and how it relates to this lab.
Appendix D

Lab Report Rubric

Name __________________

Lab Title ______________________________

Date __/___/___

Period ___

Objective:
✓ The title of your lab reflects the full scope of your investigation.
✓ The purpose of your investigation is clearly stated.
✓ You’ve stated a valid hypothesis (i.e. prediction) based on research and your present knowledge.
✓ You started an investigation with a clearly defined independent and dependent variable.

1 2 3 4

Procedure:
✓ You designed an experiment that is a valid test of your hypothesis.
✓ You assembled, listed and used the necessary materials to test your hypothesis.
✓ You outlined and followed the necessary procedure to complete a valid test of your hypothesis.
✓ Your investigation includes the necessary control measures including a control group or controlled variables.

1 2 3 4

Data and Observations:
✓ Your data are recorded with accuracy, precision, and units.
✓ Your observations are accurate, detailed, and descriptive.
✓ All formulas and calculations are shown and organized.
✓ Tables, charts, and graphs are easy to read and properly formatted.
✓ You include necessary pictures that are recognizable, detailed and labeled.

1 2 3 4

Analysis:
✓ You accurately and comprehensively interpreted your data and observations to reach a conclusion.
✓ Your conclusion includes an evaluation of your hypothesis based on the data you collected.
✓ You addressed sources of error and unexpected outcomes.
✓ You demonstrated a clear understanding of the vocabulary, facts, and concepts related to this investigation.

1 2 3 4
Presentation:
✓ You show pride in your work by editing for spelling, grammar, and mechanics.
✓ Your work demonstrates skill with computer and software technology.
✓ Your writing is easy to read and your meaning is clear and concise.
✓ The organization and presentation of your work enhances the reader’s understanding and satisfaction.

1 2 3 4

Final Grade = __________ / 20
Appendix E  

Chemistry  
Name __________________  
Class: __________  
Date: ____________

Rates of Reaction

Pre-Lab Discussion:
The rate of a chemical reaction is the time required for a given quantity of reactants to be turned into products. The rate of reaction is affected by several factors including, nature of reactants, concentration of reactants, temperature, pressure and the presence of catalysts.

A chemical reaction is the result of effective collisions between particles of reactants. Increasing the temperature of a system raises the average kinetic energy of the particles and results in more effective collisions. This affects the rate of reaction.

At a constant temperature, increasing the concentration of one or more reactants increases the number of particles present and hence the number of collisions. This also affects the rate of reaction.

In this reaction the reaction is marked by a color change. The rate of the reaction will be noted by timing the interval between the time the two solutions are mixed and the appearance of a blue color. We will be varying the concentration of one of the reactants in part one and the temperature of the reactants in part two.

Purpose:
Study the effect that changing concentration of a reactant has on the rate of a chemical change. Study the effect that changing the temperature has on the rate of a chemical reaction.

Procedure:
Part 1
1. Label two beakers ‘A’ and ‘B’. Into each beaker, measure out about 70 mL of each solution A and B.
2. Into a graduate measure out 10 mL of solution B. Pour it into a test tube.
3. Into a graduate measure out 10 mL of solution A.
4. Prepare to time the reaction. Pour A into the test tube containing B and time the number of seconds until a color change is noted. Record in data table.
5. Rinse test tube well.
6. Do same procedure 5 more times each time diluting solution A with water to vary the concentration.
### Part 2

1. Measure 10 mL of solution A and 10 mL of solution B. Put each into a separate test tube.
2. Mix the two solutions and time reaction rate. Record in data table.
3. Measure out 10 mL of A and 10 mL of B. Put each into a separate test tube.
4. Put test tubes into a beaker half filled with water. Add ice to the water until the temperature stops going down. Allow test tubes to stand in water until they are the temperature of the water bath.
5. Mix two solutions. Time reaction rate.
6. Measure out 10 mL of A and 10 mL of B. Place into two separate test tubes.
7. Put test tubes into beaker half filled with water and heat water to about 30 °C.
8. Let test tubes sit in water bath until they are about the same temperature as the warm water. Mix the two solutions and time reaction rate.

### Questions & Conclusion:

1) Graph your results on graph paper.
2) What is the effect of temperature on reaction rate? What is the effect of concentration on reaction rate?
3) How does the collision theory relate to the rate of chemical reactions?

Write a conclusion!
Appendix F

Lab Observations of an Equilibrium System

Purpose: To predict and confirm the effect that temperature and concentration have on equilibrium according to Le Chatelier’s Principle.

\[ \text{CuCl}_2^{2-} (aq) \rightleftharpoons \text{Cu}^{2+} (aq) + 4 \text{Cl}^- (aq) + \text{heat} \]

Green \hspace{1cm} Blue

Data Table:

<table>
<thead>
<tr>
<th>Stress</th>
<th>Predict</th>
<th>Result</th>
<th>Equilibrium Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cool</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add NaCl (add Cl\textsuperscript-\textsuperscript-)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add AgNO\textsubscript{3} (dec. Cl\textsuperscript-\textsuperscript-)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusion:

- Explain what we did.
- What was the purpose of the experiment?
- What is equilibrium?
- What is LeChatelier's Principle?
- How did temperature effect the reaction?
- How did concentration effect the reaction?

Make sure to answer in paragraph format!!
Appendix G

KINETICS 09

1. Which graph represents an endothermic reaction?

(1) 

(2) 

(3) 

(4) 

2. Given the reaction at equilibrium:

\[ A(g) + B(g) + \text{heat} \leftrightarrow C(g) + D(g) \]

The equilibrium will shift to the right when the
(1) pressure is decreased
(2) temperature is increased
(3) concentration of \( A(g) \) is decreased
(4) concentration of \( C(g) \) is increased

3. Given the reaction at equilibrium:

\[ N_2(g) + 3 H_2(g) \leftrightarrow 2 NH_3(g) \]

Increasing the concentration of \( N_2(g) \) will increase the forward reaction rate due to
(1) a decrease in the number of effective collisions
(2) an increase in the number of effective collisions
(3) a decrease in the activation energy
(4) an increase in the activation energy

4. The value of the equilibrium constant of a chemical reaction will change when there is an increase in the
(1) temperature
(2) pressure
(3) concentration of the reactants
(4) concentration of the products

5. Based on Reference Table 1, which reaction is endothermic?
(1) \( \text{NaOH}(s) \rightarrow \text{Na}^+(aq) + \text{OH}^-(aq) \)
(2) \( \text{NH}_4\text{Cl}(s) \rightarrow \text{NH}_4^+(aq) + \text{Cl}^-(aq) \)
(3) \( \text{CO}_2(g) + \text{O}_2(g) \rightarrow \text{CO}_2(g) \)
(4) \( \text{CH}_4(g) + 2 \text{O}_2(g) \rightarrow \text{CO}_2(g) + 2 \text{H}_2\text{O}(l) \)

6. Given the reaction at equilibrium:

\[ 2 \text{SO}_2(g) + \text{O}_2(g) \leftrightarrow 2 \text{SO}_3(g) + \text{heat} \]

Which change will shift the equilibrium to the right?
(1) decreasing \([\text{SO}_3]\)
(2) decreasing the pressure
(3) increasing \([\text{O}_2]\)
(4) increasing the temperature

7. Based on Reference Table 1, when 2.00 moles of \( \text{NaOH}(s) \) dissolves in water
(1) 44.5 kJ of energy is released and the temperature of the water increases
(2) 44.5 kJ of energy is absorbed and the temperature of the water decreases
(3) 89 kJ of energy is released and the temperature of the water increases
(4) 89 kJ of energy is absorbed and the temperature of the water decreases

8. Which interval on the potential energy diagram shown below represents the \( \Delta H \) of the reaction

\[ a + b \rightarrow c + d \]

(1) 1  (3) 3
(2) 2  (4) 4

9. A flask at 25°C is partially filled with water and stoppered. After a period of time the water level remained constant. Which relationship best explains this observation?
(1) The rate of condensation exceeds the rate of evaporation.
(2) The rates of condensation and evaporation are both zero.
(3) The rate of evaporation exceeds the rate of condensation.
(4) The rate of evaporation equals the rate of condensation.
10. In the diagram below, which letter represents the activation energy for the reverse reaction?

(1) A  (3) C  
(2) B  (4) D

11. Which conditions will increase the rate of a chemical reaction?
(1) decreased temperature and decreased concentration of reactants  
(2) decreased temperature and increased concentration of reactants  
(3) increased temperature and decreased concentration of reactants  
(4) increased temperature and increased concentration of reactants

12. The difference between the potential energy of the reactants and the potential energy of the products is
(1) $\Delta G$  (3) $\Delta S$  
(2) $\Delta H$  (4) $\Delta T$

13. In order for a chemical reaction to occur, there must always be
(1) an effective collision between reacting particles  
(2) a bond that breaks in a reactant particle  
(3) reacting particles with a high charge  
(4) reacting particles with a high kinetic energy

14. Given the equation:

$$2 \text{ CO(g)} + \text{ O}_2(\text{g}) \rightarrow 2 \text{ CO}_2(\text{g}) + 566 \text{ kJ}$$

What is the heat of reaction, in kilojoules per mole, of the CO$_2$(g) formed?
(1) +283  (3) −283  
(2) +566  (4) −566

15. As the number of moles per liter of a reactant in a chemical reaction increases, the number of collisions between the reacting particles
(1) decreases  (3) remains the same  
(2) increases

16. The graph below represents a chemical reaction.

This reaction is best described as
(1) endothermic, because energy is absorbed  
(2) endothermic, because energy is released  
(3) exothermic, because energy is released  
(4) exothermic, because energy is released

17. Given the reaction at equilibrium:

$$A(\text{g}) + B(\text{g}) \leftrightarrow AB(\text{g})$$

Which equilibrium constant, $K_{eq}$, most favors the formation of $AB(\text{g})$?
(1) $1 \times 10^{-3}$  
(2) $2 \times 10^{-4}$  
(3) $3 \times 10^{-3}$  
(4) $4 \times 10^{-12}$

18. Given the reaction:

$$\text{Mg}(s) + 2 \text{ HCl(aq)} \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2(\text{g})$$

The reaction occurs more rapidly when a 10-gram sample of Mg is powdered, rather than in one piece, because powdered Mg has
(1) less surface area  (3) a lower potential energy  
(2) more surface area  (4) a higher potential energy

19. An increase in the temperature of a system at equilibrium favors the
(1) endothermic reaction and decreases its rate  
(2) endothermic reaction and increases its rate  
(3) exothermic reaction and decreases its rate  
(4) exothermic reaction and increases its rate

20. The energy needed to start a chemical reaction is called
(1) potential energy  (3) activation energy  
(2) kinetic energy  (4) ionization energy
21. The graph below is a potential energy diagram of a compound which is formed from its elements.

Which interval represents the heat of reaction?
1. A  
2. B  
3. C  
4. D

22. A saturated solution is represented by the equation

\[ \text{AgCl(s)} \rightleftharpoons \text{Ag}^{+} \text{(aq)} + \text{Cl}^{-} \text{(aq)} \]

Which change will cause an increase in the amount of AgCl(s)?
1. a decrease in pressure
2. an increase in temperature
3. a decrease in the concentration of Ag\(^{+}\) (aq)
4. an increase in the concentration of Cl\(^{-}\) (aq)

23. Base your answers on the potential energy diagram below.

The potential energy of the activated complex is equal to the sum of
1. \(X + Y\)
2. \(X + W\)
3. \(X + Y + W\)
4. \(X + W + Z\)

24. Given the reaction at equilibrium:

\[ 2 \text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2 \text{SO}_3(g) \]

If the temperature remains constant, an increase in pressure will
1. have no effect on the equilibrium
2. shift the equilibrium to the right
3. shift the equilibrium to the left
4. change the value of the equilibrium constant

25. A system is said to be in a state of dynamic equilibrium when the
1. concentration of products is greater than the concentration of reactants
2. concentration of products is the same as the concentration of reactants
3. rate at which products are formed is greater than the rate at which reactants are formed
4. rate at which products are formed is the same as the rate at which reactants are formed

26. Given the reaction at equilibrium:

\[ \text{N}_2(g) + 3 \text{H}_2(g) \rightleftharpoons 2 \text{NH}_3(g) \]

If the pressure is increased at constant temperature, there will be an increase in the number of moles of
1. \(\text{NH}_3(g)\), only
2. \(\text{H}_2(g)\), only
3. \(\text{N}_2(g)\), only
4. both \(\text{N}_2(g)\) and \(\text{H}_2(g)\)

27. Given the reaction at equilibrium:

\[ \text{N}_2 + 3 \text{H}_2(g) \rightleftharpoons 2 \text{NH}_3(g) + \text{heat} \]

Which change will increase the amount of \(\text{NH}_3(g)\) in the system?
1. an increase in the concentration of \(\text{N}_2(g)\)
2. an increase in temperature
3. a decrease in the concentration of \(\text{H}_2(g)\)
4. a decrease in pressure

28. Which is the correct equilibrium expression for the reaction below?

\[ 4\text{NH}_3(g) + 7\text{O}_2(g) \rightleftharpoons 4\text{NO}_2(g) + 6\text{H}_2\text{O}(g) \]

\[ K = \frac{[\text{NO}_2][\text{H}_2\text{O}]}{[\text{NH}_3][\text{O}_2]} \]

(1)

\[ K = \frac{[\text{NH}_3][\text{O}_2]}{[\text{NO}_2][\text{H}_2\text{O}]} \]

(2)

\[ K = \frac{[\text{NO}_2][\text{H}_2\text{O}]}{[\text{NH}_3][\text{O}_2]^7} \]

(3)

\[ K = \frac{[\text{NH}_3][\text{O}_2]^7}{[\text{NO}_2][\text{H}_2\text{O}]} \]

(4)
29. Base your answer to the following question on the table below, which represents the production of 50 milliliters of CO₂ in the reaction of HCl with NaHCO₃. Five trials were performed under different conditions as shown. (The same mass of NaHCO₃ was used in each trial.)

<table>
<thead>
<tr>
<th>Trial</th>
<th>Particle Size of NaHCO₃</th>
<th>Concentration of HCl</th>
<th>Temperature (°C) of HCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>small</td>
<td>1 M</td>
<td>20</td>
</tr>
<tr>
<td>B</td>
<td>large</td>
<td>1 M</td>
<td>20</td>
</tr>
<tr>
<td>C</td>
<td>large</td>
<td>1 M</td>
<td>40</td>
</tr>
<tr>
<td>D</td>
<td>small</td>
<td>2 M</td>
<td>40</td>
</tr>
<tr>
<td>E</td>
<td>large</td>
<td>2 M</td>
<td>40</td>
</tr>
</tbody>
</table>

Which two trials could be used to measure the effect of surface area?
(1) trials A and B  
(2) trials A and C  
(3) trials A and D  
(4) trials B and D

30. Given the reaction:

\[ A + B \rightarrow AB \]

The table below shows student data obtained about the rate of reaction when the concentration of solution A is kept constant and the concentration of solution B is changed by adding H₂O. Based on the data, the student should conclude that the

<table>
<thead>
<tr>
<th>Trial</th>
<th>Volume of Solution A</th>
<th>Volume of Solution B</th>
<th>Volume of H₂O Added</th>
<th>Reaction Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 mL</td>
<td>10 mL</td>
<td>0 mL</td>
<td>2.8 sec</td>
</tr>
<tr>
<td>2</td>
<td>10 mL</td>
<td>5 mL</td>
<td>5 mL</td>
<td>4.9 sec</td>
</tr>
<tr>
<td>3</td>
<td>10 mL</td>
<td>3 mL</td>
<td>7 mL</td>
<td>10.4 sec</td>
</tr>
</tbody>
</table>

(1) concentration has no effect on the reaction rate  
(2) reaction rate increased when H₂O was added  
(3) reaction rate increased as solution B was diluted  
(4) reaction rate decreased as solution B was diluted
Base your answers to questions 31 through 33 on the information and potential energy diagram below.

Chemical cold packs are often used to reduce swelling after an athletic injury. The diagram represents the potential energy changes when a cold pack is activated.

31. Identify a reactant listed in Reference Table 1 that could be mixed with water for use in a chemical cold pack.

32. Which lettered interval on the diagram represents the heat of reaction?

33. Which lettered interval on the diagram represents the potential energy of the products?

34. Base your answer to the following question on the information below.

Given the equilibrium equation at 298 K:

\[
\text{KNO}_3(s) \rightleftharpoons K^+(aq) + \text{NO}_3^-(aq)
\]

Describe, in terms of LeChatelier's principle, why an increase in temperature increases the solubility of KNO₃.
Base your answers to questions 35 and 36 on the information and diagram below, which represent the changes in potential energy that occur during the given reaction.

Given the reaction: \( A + B \rightarrow C \)

![Potential Energy Diagram](image)

35. a. Does the diagram illustrate an exothermic or an endothermic reaction?
   
   b. State one reason, in terms of energy, to support your answer.

36. On the diagram provided draw a dashed line to indicate a potential energy curve for the reaction if a catalyst is added.

37. Base your answer to the following question on the information below.

   A student wishes to investigate how the reaction rate changes with a change in concentration of HCl(aq).

   Given the reaction:
   
   \[ \text{Zn}(s) + \text{HCl}(aq) \rightarrow \text{H}_2(g) + \text{ZnCl}_2(aq) \]

   Identify one other variable that might affect the rate and should be held constant during this investigation.
38. Given the reaction at equilibrium:

\[ \text{N}_2(g) + 3 \text{H}_2(g) \leftrightarrow 2 \text{NH}_3(g) + 92.05 \text{ kJ} \]

a. State the effect on the number of moles of \( \text{N}_2(g) \) if the temperature of the system is increased.

b. State the effect on the number of moles of \( \text{H}_2(g) \) if the pressure on the system is increased.

c. State the effect on the number of moles of \( \text{NH}_3(g) \) if a catalyst is introduced into the reaction system. Explain why this occurs.

39. Base your answer to the following question on the information below.

Given the reaction at equilibrium:

\[ 2\text{NO}_2(g) + 7\text{H}_2(g) \leftrightarrow 2\text{NH}_3(g) + 4\text{H}_2\text{O}(g) + 1127 \text{ kJ} \]

Complete the potential energy diagram above for the forward reaction. Be sure your drawing shows the activation energy and the potential energy of the products.
40. Base your answers to the following questions on the information below and your knowledge of reaction kinetics.

Maltase is an enzyme used by humans which speeds up the process of breaking down the disaccharide, maltose, into a smaller sugar called glucose. In this reaction, maltase is unaffected.

a. What is another name for a substance that can affect the rate of chemical reaction?

b. Why are enzymes so important to humans? Explain.

41. Base your answers to the following questions on the information below.

Cold packs are often used to prevent swelling of certain athletic injuries. The pack contains ammonium nitrate and water in separate compartments. When the pack is squeezed, the partition breaks mixing the components and forming a solution which turns very cold.

Below is the reaction:

\[ \text{NH}_4\text{NO}_3(\text{s}) \rightarrow \text{NH}_2\text{NO}_3(\text{l}) \]

a. Based on the information above, is the reaction endothermic or exothermic?

b. Based on the information above, is there an increase or decrease in entropy of the system within the cold pack if it is used? Explain your answer.