

## Part C. A Mental Arithmetic Activity Packet

For instructors, an introduction to the use of this packet is provided at <http://chemreview.net/blog/?p=409>.



### Mental Math Packet – Detail for Instructors

- Level:** The “mental math” packet is intended for courses aiming to *prepare* students for General or AP Chemistry. Activity #2, however, may also be appropriate in an AP preparation “summer packet.”
- Goals:** To assess, and strengthen if needed, fluency in mental arithmetic.
- Timing:** Activity #1 (a 4 minute quiz) is recommended for Week 1 or 2 of classes. The use of the additional activities will depend on the results of the quiz.
- Parts:** This packet contains, in this order:
- A **summary** of the four mental math activity options.
  - **Detail** on the activity options.
  - An **overview of research** on the importance of mental math in chemistry.

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### Summary: Mental Arithmetic Activity Options:

- Act. #1. **4 Minute Quiz:** This quiz on mental math fundamentals is designed to be administered at or before the time that students start mathematical topics in courses designed to *prepare* students for AP or college chemistry.
- Act. #2. **Mental Math Practice:** This activity consists of three online homework assignments that practice addition, subtraction, and multiplication. Each assignment concludes with a one-minute online quiz that students can retake multiple times (to encourage improving their performance) and submit their one best quiz via email.
- Act. #3. **Simplifying Fractions:** This worksheet is designed to be started in class so that the instructor can provide guidance on how to simplify calculations and/or estimates of numeric answers.
- Act. #4. **Multi-digit Multiplication and Division:** Practice with the standard algorithms for multiplication and division without a calculator. (added 8/4/15)
- Act. #5. **Other Resources:** For students who need more help in learning mental math than Activity #2 provides, this assignment is an option that encourages students to find a different method that works for them.

## To the Instructor

### Mental Arithmetic Activity #1 -- *Mental Arithmetic Quiz*

Activity #1 is a quiz that tests the ability of students to add, subtract, multiply, and divide simple numbers without a calculator. The quiz is included in this PDF but it is also in the MSWord file at [www.ChemReview.Net/WeekOneEditable.docx](http://www.ChemReview.Net/WeekOneEditable.docx) in a format you may *edit* if you choose.

The quiz will identify students who need additional practice in the quick, accurate recall of math facts.

- On Quiz page 1 are the instructions for the students. Page 2 is the quiz, to be printed on the back of Page 1.
- The paper is designed to be folded in half and stapled so that the page 2 quiz is hidden inside, but the Page 1 instructions outside can be read by the student before the timed quiz begins.

There are two versions of Page 2. The questions are the same but in a different order on each version. To discouragewandering eyes, you may want to print half with one Page 2, half with the other, shuffle and hand them out randomly, then separate the versions when you grade.

To have the automaticity that is necessary to avoid bottlenecks in working memory, students must be able to *recall* rather than calculate fundamentals. It is therefore recommended that the total time limit for these 60 questions be **4 minutes**. Students who know their math facts are often able to finish with perfect scores in less than 3 minutes.

You may want to announce when there are 2 minutes remaining. Not all will finish.

It may speed grading if a grade of “R” (Re-test) is quickly assigned when result is obvious..

Students from states with math standards that in past years emphasized mental arithmetic may not need Activity #2 to strengthen their mental math, but the quiz should identify those students who do.

We suggest a tough grading scale. Students need to be able to do mental math quickly and *accurately*. Those borderline or rusty will benefit from the practice in Activity #2.

The instructions include language on *re-tests* that you may want to edit. In our experience, if students expect they will be able to take re-tests or that “the lowest grade will be dropped,” they tend to find excuses not to study. However, we suggest the re-test should be offered in this *one* case (because the results depend in part on K-12 state math policies on calculator use over which students had no control), while making it clear that on re-tests, this quiz is an exception.

Suggested oral quiz instructions:

1. (Before handing out): “Do *not* open this quiz. Do read the instructions.”
2. (After handing out): “Do not open the quiz until I say ‘begin.’ This is a timed quiz. You may *not* use a calculator. Write your answers quickly. Skip questions you cannot answer quickly. Cross out errors – don’t erase. You may use pencil or pen. Ready? Begin.”

# # # # #

(staple)

# Mental Arithmetic Quiz

PRINT your name here. → \_\_\_\_\_

## Directions:

**Do NOT open this to view the inside until you are told to do so.** This is a timed quiz. It tests how well you can do *arithmetic automatically* -- withOUT a calculator.

This quiz counts. However, if “fast math” is something you need to practice, you will be given an opportunity to study and to take a re-quiz that will replace this grade.

Usually, this course does *not* allow re-tests. This first quiz is an exception because this material has not been taught in this course but you may need to review.

Nearly always in chemistry, you need to work carefully and check your work. But, on *this* one quiz, work quickly to get as many problems right as you can. If you cannot answer a question within **2-4** seconds, *skip* to the next question.

Answer all questions in the *boxes* provided on this paper. Make corrections if needed by crossing out errors (not erasing). You may NOT use ANY type of calculator.

Your instructor will tell you the time limit and when to open to the quiz on the page inside.

(fold) - - - - -

### Arithmetic Timed Quiz

Answer each *quickly* in the box provided. *Skip* questions you *cannot* answer quickly.

1. **Multiplication.** Fill in the boxes below.

$8 \times 9 =$		$8 \times 4 =$		$9 \times 5 =$		$3 \times 9 =$	
$4 \times 3 =$		$6 \times 6 =$		$5 \times 4 =$		$8 \times 3 =$	
$7 \times 5 =$		$7 \times 9 =$		$8 \times 8 =$		$5 \times 5 =$	
$8 \times 6 =$		$5 \times 3 =$		$5 \times 7 =$		$7 \times 8 =$	
$6 \times 4 =$		$7 \times 7 =$		$5 \times 8 =$		$7 \times 4 =$	
$9 \times 4 =$		$6 \times 5 =$		$6 \times 3 =$		$9 \times 6 =$	

2. **Addition:**

$8 + 9 =$		$8 + 4 =$		$9 + 5 =$		$3 + 9 =$	
$4 + 13 =$		$16 + 6 =$		$25 + 4 =$		$8 + 33 =$	
$4 + 45 =$		$7 + 59 =$		$8 + 88 =$		$5 + 64 =$	

3. **Subtraction:**

$18 - 9 =$		$8 - 4 =$		$9 - 5 =$		$13 - 9 =$	
$24 - 13 =$		$16 - 6 =$		$25 - 4 =$		$28 - 3 =$	
$54 - 45 =$		$67 - 5 =$		$88 - 18 =$		$25 - 13 =$	

4. **Division** ( / means “divided by” ) :

$18 / 9 =$		$32 / 4 =$		$45 / 5 =$		$63 / 9 =$	
$42 / 7 =$		$54 / 6 =$		$72 / 12 =$		$27 / 3 =$	
$96 / 8 =$		$56 / 7 =$		$12 / 24 =$		$3 / 12 =$	

(staple)

## Arithmetic Timed Quiz

Answer each *quickly* in the box provided. *Skip* questions you *cannot* answer quickly.

1. **Multiplication.** Fill in the boxes below.

$8 \times 4 =$	
$6 \times 6 =$	
$7 \times 9 =$	
$5 \times 3 =$	
$7 \times 7 =$	
$6 \times 5 =$	

$8 \times 9 =$	
$4 \times 3 =$	
$7 \times 5 =$	
$8 \times 6 =$	
$6 \times 4 =$	
$9 \times 4 =$	

$3 \times 9 =$	
$8 \times 3 =$	
$5 \times 5 =$	
$7 \times 8 =$	
$7 \times 4 =$	
$9 \times 6 =$	

$9 \times 5 =$	
$5 \times 4 =$	
$8 \times 8 =$	
$5 \times 7 =$	
$5 \times 8 =$	
$6 \times 3 =$	

2. **Addition:**

$8 + 4 =$	
$16 + 6 =$	
$7 + 59 =$	

$8 + 9 =$	
$4 + 13 =$	
$4 + 45 =$	

$3 + 9 =$	
$8 + 33 =$	
$5 + 64 =$	

$9 + 5 =$	
$25 + 4 =$	
$8 + 88 =$	

3. **Subtraction:**

$8 - 4 =$	
$16 - 6 =$	
$67 - 5 =$	

$18 - 9 =$	
$24 - 13 =$	
$54 - 45 =$	

$13 - 9 =$	
$28 - 3 =$	
$25 - 13 =$	

$9 - 5 =$	
$25 - 4 =$	
$88 - 18 =$	

4. **Division** ( / means “divided by” ) :

$32 / 4 =$	
$54 / 6 =$	
$56 / 7 =$	

$18 / 9 =$	
$42 / 7 =$	
$96 / 8 =$	

$63 / 9 =$	
$27 / 3 =$	
$3 / 12 =$	

$45 / 5 =$	
$72 / 12 =$	
$12 / 24 =$	

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## **To the Instructor -- *Mental Arithmetic Assignment #2* --**

### ***Mental Math Homework -- Practice and Online Quizzes***

This assignment is recommended for students who did not achieve a near perfect score on the 4-minute quiz.

In this assignment, to improve their arithmetic fluency, students practice recall of math fact fundamentals, then take an online quiz and submit their results by email.

It helps with motivation if students assume their emails “count,” and the work they do on the assignment will indeed count toward improving their skills, and you may want to check for receipt of the email. However, rather than grading the emails, it is suggested that the “4-minute quiz” be re-administered at some point soon after the deadline for the third and final email, with the higher grade of the two quizzes the one that “counts.” The 4 minute quiz will likely take less time to grade than the emails.

At this point, it will help if you would read and complete a sample portion of the “Mental Math Homework” assignment on the following pages as far as the end of **Quiz 1**, then return here.

\* \* \* \* \*

The assignment is included in this PDF for viewing but it is also in the MSWord \*docx file at [www.ChemReview.Net/WeekOneEditable.docx](http://www.ChemReview.Net/WeekOneEditable.docx) . You will need to substitute into that file at the points **in red**. Once that is done, the file can be saved as a PDF and web-posted or copied and handed out.

You may want to set up a special email address to receive these -- or a filter that sends “.Quiz” in the address line to a special folder in your in-box.

Each assignment sets a standard that all students should be able to reach with effort. Especially on the multiplication and division, it is important that the students be able to solve by fast automated recall, rather than slower “calculation.”

On deadlines: allowing about 3 study days per assignment is recommended. For students who were not required to learn their times tables in the past, practice for several days will be required to build long-term retention. If most students need only to “refresh their memory” on these fundamentals, 2 days per assignment may be sufficient.

### **Alternatives**

.Given the wide variety of K-12 math approaches used in states and districts in the past 10 years, student outcomes are difficult to predict in advance, and may change in future years due to changes in state math standards. Our advice would be to give the 4-minute quiz. If needed, try Activity #2, re-quiz, and evaluate whether some students need additional work.

In Activity #4, we suggest ways to have students locate additional programs that may be used to teach and quiz on mental math. With the technology changing quickly, you may want to evaluate and substitute those for this assignment in future years.

The two pages of Activity #2 that are to be posted or handed out to students are on the following pages.

Addendum:

The assignment in Activity #2 is “flash-based.” A note about trying different browsers has been added for cases in which this is an issue. We are looking for additional assignment option which works on different tablet and smartphone operating systems. We will update this assignment as soon as a suitable options are found.

Meanwhile, on most computers and laptops with standard keyboards, multiple browsers should be available that work with the current project.

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## ***Mental Math Homework -- Practice and Re-Quiz***

To solve science problems, you need to be able to solve *simple* math quickly and accurately -- without a calculator. If your math facts are rusty, this exercise will catch you up.

You will take 3 online quizzes – no calculators allowed.

You will need a computer or laptop with a *numeric keypad* that is easy for you to use, plus a way to take “screen shots.” Instructions for taking screenshots on a standard “windows” computer are given below. To use a different computer, search “screen shots” and your operating system.

To start, go to <http://www.mathsisfun.com/numbers/math-trainer-multiply-old.html>

(The “trainer” is “flash based.” When you open the link above, if the “math trainer” shown in the middle of the screen on the next page is not visible, try accessing the link above from a different browser. If the option is given to “load flash,” do so for this application.)

**Quiz 1:** Set the **workout** type in the left side window to **Add** . Click on the *next to last* button below (2+2 to 12+12 ) . Set the timer at **zero** and practice until you know them all, fast. You will get better with practice!

It takes a few tries to learn the system. After entering an answer, you will likely not need to hit *enter*). The backspace key usually works if the first digit of two is typed incorrectly.

To vary practice, try some of the other types of practice on this site, *or* make flashcards, *or* download a set of flashcards for your smartphone that you can use for practice during “downtimes.”

Then: Set the timer at **one** minute and take a **one** minute quiz. You may re-take the quiz as many times as you like.

Via email, send me your *best* score via email that has at least **94%** right. If you get to **26 or more right** with 94% or better accuracy, *stop*, email the screenshot with that score, and move on to the next assignment.

Use the “How to Send” instructions below. The deadline for **Quiz 1** is: **X PM Xdate.**

**Quiz 2:** Set the **workout** type in the left side window to **Subtract** . Click on the *last* button below (9-2 to 20-12 ). Set the timer at **zero** and practice until you know them all, fast.

Then set the timer at **one** minute and take a **one** minute quiz. Email me your best score based on the “94%/26” rule above and “send” instructions below.

Deadline for **Quiz 2:** **X PM Xdate.**

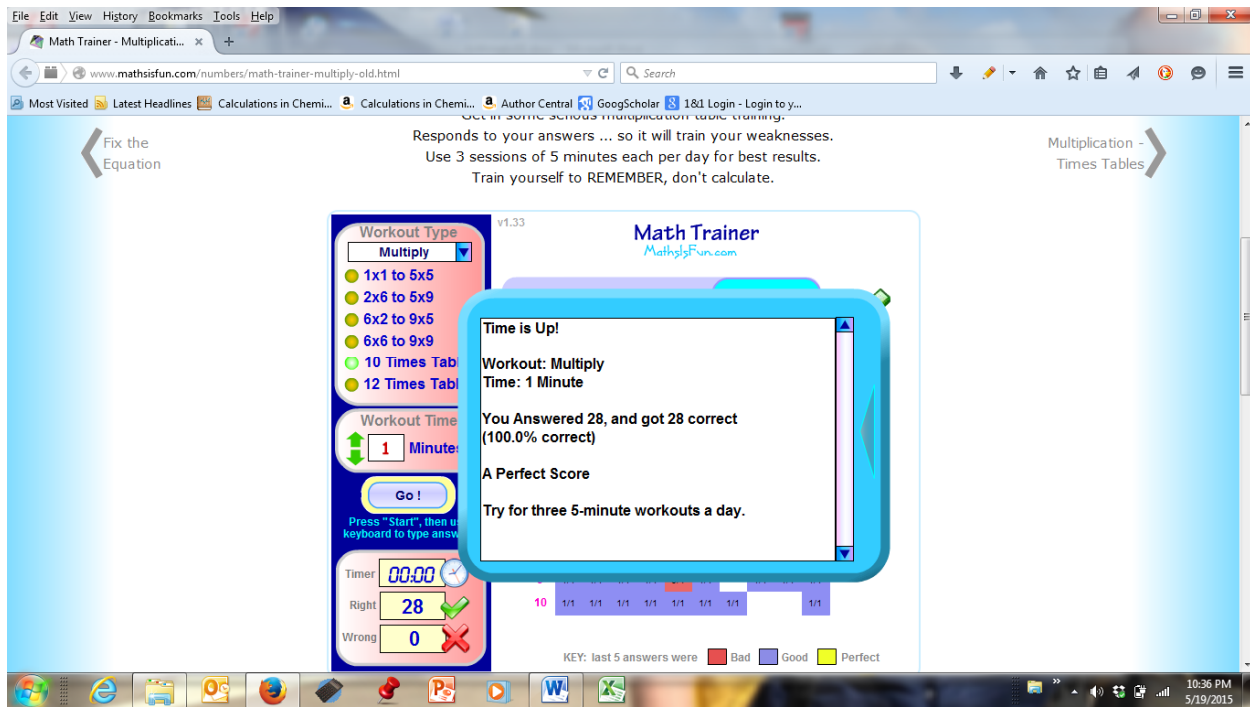
**Quiz 3:** Set the **workout** type in the left side window to **Multiply** . Click the radio button that says “**12** times tables.” Set the timer at **zero** and practice your multiplication tables until you can do each card in 3 seconds or less. Then: Set the timer at **one** minute, take a **one** minute quiz, and mail your best score using the same rules as above.

Deadline for **Quiz 3:** **X PM Xdate.**

### **How to Send In Your Scores:**

At the end of the 1 minute quiz, you will have a screen that looks something like this:





1. SAVE your screenshot when you get a quiz score that you think is the best you can do for now. *To save:*

Make sure the blue score window in the middle -- and the current date and time somewhere (see bottom right here) -- all show.

Press PRTSC to copy a “full” screen shot like the one above that shows the “Workout Test” type and 1 minute. Then

  - a. Paste it into the PAINT program listed at START>All Programs>Accessories that comes with Windows OR paste it into any program that will save the screen shot .
  - b. SAVE the file in the filename format: Your last name DOT Firstname DOT QuizNumber DOT Your number right on the quiz.
    - Example: Smith.Jane.Quiz1a.26.(ext) for your first Quiz1 submission.*
  - c. If you get a better score later, save as Quiz1b in name, and Quiz2a and 2b for quiz 2, etc.
2. To send your *best* score:
  - a. Send your saved screenshot file in an email as an attachment.
  - b. On the subject line, put the name of the attachment above.
  - c. Email it to **XXXXXX** .
3. To be sure you meet each deadline, you may email up to two files. This lets you send a good score, then a higher score if you get one just before the deadline. But at 94% or above right with 26 or above right, send that email and go to the next assignment.

That's it! Get started working on Quiz 1 quickly! Practice several times a day!

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## To the Instructor

### ***Mental Arithmetic Activity #3 –***

#### ***Using Mental Math to Simplify Fractions***

Activity #3 is practice at the numeric simplification that is often useful in scientific calculations and when estimating to check a calculator answer.

The worksheet below is included in this PDF but it is also in the MSWord file at [www.ChemReview.Net/WeekOneEditable.docx](http://www.ChemReview.Net/WeekOneEditable.docx) in a format you may *edit* if you choose.

If students have not had ample prior practice in this type of mental arithmetic, you may want to start by having them in class try *one* of each type of question here (fraction, doubling, halving), then show them on the board how you would simplify each case, then let them do and check the rest on their own.

The worksheet should take about 20 minutes to discuss and complete. You may want to save parts of each section for homework or for warmup in a following lesson.

This assignment is designed to be done just after students have completed **Quiz 3** of **Activity #2** above (achieving initial mastery of multiplication tables). This will work as “spaced overlearning” if they are able to apply multiplication and division that has previously been well memorized.

That schedule may have students completing this assignment after they are asked to use mental math in multiplication and division in the Chapter 1 (Scientific Notation) of the *Calculations* text (included in the free online chapters). However, most of the Chapter 1 numbers rely on *very* simple mental math. Students will be asked to apply the more typical mental math simplifications that are practiced in this worksheet at multiple points later in scientific calculations during the course.

If you have time in a later class to repeat this type of exercise, it should be easy to change some numbers on the editable version of the file to make a new version.

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## Using Mental Math to Simplify Fractions

WithOUT a calculator, use your mental math skills to reduce these fractions to a one or two digit whole number. Show your work on this paper. Check your answers at the bottom.

Each problem may have multiple ways to cancel and solve. Any way to a correct answer works.

$$1. \text{ Example: } \frac{8 \times 15 \times 3}{72} = \frac{\cancel{8} \times 15 \times 3}{\cancel{72} 9} = \frac{\cancel{8} \times 15 \times \cancel{3}}{\cancel{72} \cancel{3}} = \frac{15}{3} = 5$$

(You are not required to recopy the problem. Marking cancellations on this paper is recommended. However, in a long problem, you may want to re-write at some point, as in the “next to last” step above, just to keep your progress clear.)

Hint: It usually helps to try to reduce the larger numbers on both the top and bottom first.

$$2. \frac{56 \times 2 \times 3}{4 \times 7} =$$

$$7. \frac{20 \times 4 \times 45}{8 \times 9} =$$

$$3. \frac{35 \times 24 \times 5}{2 \times 6 \times 7} =$$

$$8. \frac{16 \times 12 \times 7}{2 \times 96} =$$

$$4. \frac{63 \times 4 \times 42}{6 \times 7 \times 9} =$$

$$9. \frac{10 \times 18 \times 56}{8 \times 2 \times 30} =$$

$$5. \frac{48 \times 6 \times 11}{4 \times 18} =$$

$$10. \frac{8 \times 27 \times 56}{7 \times 9 \times 32} =$$

$$6. \frac{35 \times 2 \times 8}{40 \times 14} =$$

$$11. \frac{28 \times 60}{12 \times 7 \times 2} =$$

12. Double these:    42        17        36        45        16        24        32        48

13. Cut these values in half:    44        98        86        38        46        78        56

**Answers:** 2. 12    3. 50    4. 28    5. 44    6. 1    7. 50    8. 7    9. 21    10. 6

11. 10    12. 84    34    72    90    32    48    64    96    13. 22    49    43    19    23    39    28

**To the Instructor:**

***Mental Arithmetic Activity #4 --***

**Multi-digit Multiplication and Division**

The worksheet below reviews the standard algorithms for multiplication and for very simple long division.

Using the multiplication algorithm requires students to practice recall of both multiplication and addition. The division algorithm requires practice of multiplication, division and subtraction skills.

The benefits of requiring students to occasionally perform these types of calculations include

- They are an easy way to promote the “overlearning” of fundamentals that science says is necessary to see quantitative relationships;
- Problems like these can be put on the board at the start of a class throughout the term for productive work while you do administrivia;
- Questions like these can be advertised as “to be expected” on any quiz where a calculator should not be necessary (such as on bonding topics later in the course), as a way to convey the need for frequent review of arithmetic fundamentals

The worksheet can be assigned as homework, or you can demonstrate one problem for each of the two algorithms and leave remaining problems for deskwork or self-study.

The background of students on these topics may vary widely depending on what type of elementary math curriculum was in use in each student’s school, district, or state.

In recent years, under “K-12 math standards” in some states, students were never taught long division. In many widely adopted elementary arithmetic texts, students in lower grades were encouraged to “construct their own algorithms” for multiplication and division (you can guess how this worked for 4<sup>th</sup> graders). You may want to assign a few problems of each type and then glance at a few papers to get an idea of what expertise your students have for these procedures.

The Common Core math standards require teaching these two standard algorithms, but when and how this will impact your students in upcoming years is difficult to predict.

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## Multi-digit Multiplication and Division

To understand the numeric relationships in science, you need to be able to do arithmetic quickly “in your head.” One way to keep your mental math skills sharp is to occasionally solve simple multi-digit multiplication and division problems without a calculator. To do this without overwhelming “working memory” (where you think), you need to apply a “standard algorithm.”

1. The multiplication algorithm usually taught in the US includes these steps. For  $76 \times 42 = ?$

$$\begin{array}{r} \text{Step 1:} \quad 176 \\ \times \underline{42} \\ 152 \end{array} \qquad \begin{array}{r} \text{Steps 2 and 3:} \quad 276 \\ \times \underline{42} \\ 152 \\ \underline{304} \\ \mathbf{3192} \end{array} \quad \leftarrow (\text{putting a } \mathbf{0} \text{ after the } 4 \text{ is an option})$$

For step by step directions if needed, search online for “Standard multiplication algorithm video.”

Without a calculator, working on this paper, multiply these:

$$\begin{array}{llll} \text{a.} & \begin{array}{r} 95 \\ \times \underline{16} \end{array} & \text{b.} & \begin{array}{r} 84 \\ \times \underline{73} \end{array} & \text{c.} & \begin{array}{r} 39 \\ \times \underline{62} \end{array} & \text{d.} & \begin{array}{r} 57 \\ \times \underline{48} \end{array} \end{array}$$

2. The “long division” algorithm usually taught in US education includes these steps:

$$\text{For } 2048 \div 8 = \begin{array}{r} \underline{2} \\ 8 \overline{) 2048} \\ \underline{16} \\ 44 \end{array} \qquad \begin{array}{r} \underline{256} \\ 8 \overline{) 2048} \\ \underline{16} \\ 44 \\ \underline{40} \\ 48 \\ \underline{48} \end{array} = \mathbf{256}$$

For step by step directions if needed, search online for “Standard long division algorithm video.”

Without a calculator, try these “evenly divisible” cases (the answer will be a multi-digit whole number -- no decimals or remainders).

$$\begin{array}{lll} \text{a.} & \overline{6) 516} & \text{b.} & \overline{9) 2187} & \text{c.} & \overline{8) 5560} \end{array}$$

**To the Instructor:**

**To the Instructor: Assignment 5 –**

***Finding A Better Way to Learn Times Tables***

In this assignment, students are asked to find and evaluate some free computer or tablet or smartphone games that can help in learning times tables.

For students who do not do well on the re-test for whatever reason, this activity is one more chance to learn the material – by finding a different method that works for them.

OR -- if you offer “extra credit” assignments or “project” assignments at any point during the course, this assignment might be a possible option.

The reference to *Anki* and *Supermemo* as programs that help with recall are optional, but many reviewers have found those helpful in learning math and science fundamentals.

The assignment is included in this PDF for viewing but it is also in the MSWord \*docx file at [www.ChemReview.Net/WeekOneEditable.docx](http://www.ChemReview.Net/WeekOneEditable.docx) . You will need to substitute at the points **in red**. Once that is done, the file can be saved as a PDF and web posted, or copied and handed out.

Over time, there will likely be a growing number of free online options that help students gain fluency in mental math recall. If your students find one or more that look promising, please let us know at [ChemReviewTeam@ChemReview.Net](mailto:ChemReviewTeam@ChemReview.Net) .

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## ***Math Facts Assignment #5***

### **Finding A Better Way to Learn Times Tables**

In this assignment, you are asked to look on the web for free software (including computer games, flashcard programs, smartphone apps) that both teach times tables effectively and make learning times tables more enjoyable.

Your goal is to hand in a 1 to 1 1/2 page report giving your recommendations on what programs to advise students to use and why: What are the pro's and con's of each free system for learning? The steps are:

1. Start with the *MathIsFun* website assignment for **Quiz 3**.

Practice **2 sessions of 5 minutes each** per day for **2 days**.

Start with button #1 ("1x1 to 5x5") the first day, and the next button down (#2) the 2<sup>nd</sup> day.

Then set the timer at **one** minute, with button #2 on, and take a one minute quiz.

Decide if this practice helped. Include your answer to that question in your paper.

2. Do an online search on "multiplication flashcard free computer games" and on "learning times tables" for a computer, tablet, or your smartphone. Look for free games to try.

As one approach, you may want to evaluate either Anki (importing the primary math stack) or Supermemo 2004 (free).

Try at least 2 systems in addition to the *MathIsFun* in Step 1, compare the systems, and state which one you like best and why.

A key condition: The game or system must teach at least up to 12 x 12 for free, rather than only do a few flashcards for free.

3. So, what's the best way for students to learn their times tables? Type up your report and email it to me at **XXXX**. Deadline: **XXXX**.

4. **If you are doing this assignment as a "re-quiz" grade, do the multiplication (Quiz 3) assignment one more time and submit your result via email. Deadline? Same as in Step 3 above.**

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## **Mental Arithmetic: Background and Research**

### **The Importance of Mental Math**

Data from two sources indicate that “arithmetic fluency” (effortless, immediate, accurate recall of simple arithmetic facts) is crucial for success in quantitative science courses. Empirically, studies by Wagner, Sasser, and DiBiase (JCE 2002), Cooper and Pearson (J. Sci. Ed. Tech. 2012), and Leopold and Edgar (JCE 2008) all found that a highest predictor of success in general chemistry among the multiple variables studied was a test of simplified math calculations with no calculators allowed.

Cognitive science also cites the importance of mental math in learning to solve scientific calculations. Findings include:

- Students able to do simple mental math quickly can better understand quantitative examples and proportional reasoning encountered during class and in texts.
- If students have *not* mastered their times tables, explanations based on doubles, halves, squares, and “simple whole number ratios” for them may not be simple.
- Having to remember a calculator answer, even for the brief transfer to paper where a problem is being solved, stores data in one of the 3-5 slots in novel working memory (WM). That storage may bump out of WM an element needed for problem solving.
- If answers to simple problems can be recalled fluently, more room is available in WM for constructing links to context cues: A process that builds conceptual understanding.

Cognitive experts emphasize that to learn quantitative relationships efficiently and effectively, students need to have more than “moderate” skills in mental math: They need *fluency*. The most efficient process to develop fluency is “spaced *overlearning*.” Practice to achieve fast, 100% accurate recall repeated for several days, accompanied by problem-solving that applies mental math to calculations with simple numbers.

Activity #2 is designed to assist students in overlearning math facts. Later lessons and problems in *Calculations In Chemistry* are designed to develop and strengthen both arithmetic and algebraic fluency.

### **Student Background**

From 1990 to 2010, before the importance of math fluency was identified by cognitive research, K-12 math standards in most US states required calculator use on 3<sup>rd</sup> grade state math tests and de-emphasized “mental math.” As one result, the math fluency of the current student generation varies *widely* depending on the policies of states and districts that were in place during their early schooling.

Under those circumstances, the only way to know how well any cohort of students knows mental math is to test them.

Cognitive research does *not* suggest avoiding calculators to solve *complex* problems. What is recommended is to require the use of mental math often enough that it is ready when needed to understand simple quantitative relationships (estimating to check calculator answers, handling exponentials, balancing equations, looking for half-lives in kinetics data, etc.).



For students found to have fluency deficits, the activities in this packet are experiments designed to get all students to the “starting gate” for the study of chemistry. We hope to hear from instructors on how these work and of better ideas for promoting arithmetic fluency.

### **Common Core Impact**

The arithmetic fluency of students may change over time due to the adoption in most states of the Common Core standards. The Common Core math standards emphasize arithmetic fluency, as recommended by cognitive research. The major Common Core tests (PARCC and SBAC) do not permit calculator use until 6<sup>th</sup> grade, an improvement over past standards in most states. However, the rate of change in mental math skills for students currently “in the K-12 pipeline” is difficult to predict.

### **Research**

For citations of research and additional reading on the importance of math fluency, see: [www.ChemReview.Net/CogSciForChemists.pdf](http://www.ChemReview.Net/CogSciForChemists.pdf) .

### **Quizzes**

The *quizzes* we supply in Section A (for Modules 1 and 2) are designed to be “no calculator.” The problems in our later lessons frequently use simple numbers and encourage mental arithmetic, and *some* of the later quizzes we supply with *Calculations In Chemistry*, for both the “Introductory” and “General/AP” versions, can also be done using simple mental math.

### **Caveats**

The activities in this packet are experimental procedures. How much they can compensate for 10 past years when some states over-emphasized calculator use we do not know, but we believe the activities can help.

In our view, asking students to master their times tables is not “remedial” if it is not something that their curriculum asked them to do.

Feedback on any and all aspects of this experiment is appreciated to [ChemReviewTeam@ChemReview.Net](mailto:ChemReviewTeam@ChemReview.Net) .

Additional activities will be posted and user comments will be added at the bottom of this file over time: Check back close to your “start” date if you have a chance.

Change #1: The directions to try different and “flash based” browsers was added on 8/1/15.

Change #2: The “standard algorithm” activity #4 was added on 8/4/15.

**(End of this packet)**