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To Instructors -

Acid-Base Math Review – As Homework

Below are two pages of practice in the math of solving for $[H^+]$ and $[OH^-]$ in strong acid and base solutions -- both with and without a calculator.

In General, GOB, and AP Chemistry, these problems are intended to be a math review conducted via homework assignment (a suggested assignment format is below).

In HS Chem or college Prep Chem, you may want to put up and model solving a few similar problems in class, and then assign the homework as reinforcement.

This packet includes a brief quiz to encourage homework completion.

Scope

The practice problems below ask students to write answers (in scientific notation) to calculations including these:

a. $\dfrac{1.0 \times 10^{-14}}{2.0 \times 10^{-4}} =$ b. $\dfrac{10^{-14}}{0.0080} =$ c. $(7.9 \times 10^{-7})\ (x) = 1.0 \times 10^{-14}$; $x =$

Students are asked to solve (a) and (b) with*out* a calculator. On (c), they are asked to *estimate* an answer, then solve precisely with a calculator, and compare the answers.

When learning to solve calculations, cognitive studies recommend that students be given practice problems -- and quizzes on that practice –- that include:

A. Solving calculations containing complex numbers *with* a calculator,

B. Estimating answers to complex-number problems with*out* a calculator, and

C. Solving conceptual problems contrived to have simplified numbers by mental math -- without a calculator.

For reasons science recommends that at least some problems and quizzes ask for "calculations without a calculator," see the section **Calculator Use: What Science Says** on the next page.

Are They Ready?

If your students have previously practiced applying mental math to solve exponential calculations, the two pages of problems should "refresh their memory" without requiring additional preparation.

If you are uncertain about your students' mental math skills, consider giving the 15-minute mental math quiz at www.ChemReview.Net/MentalMathAssessment.PDF

If you know your students have *not* had much practice using mental math to solve exponential calculations, before assigning the acid-base math below, it is recommended they be asked to complete Lessons **1.2** to **1.4** at https://www.ChemReview.Net/ExpoMetric.PDF . Those 3 lessons, which students should be able to easily complete as homework over 2-3 days, cover the basics of the exponential math pre-requisite for the acid-base fundamentals.

For additional mental math practice, see www.ChemReview.Net/MentalMath.PDF .

Suggested Assignment Format

The practice below is also posted online as a stand-alone PDF. A suggested homework assignment would be to (A) hand out hard copies of the two pages to students for whom computer or internet access at home may be an issue, but for others to (B) post the following:

> **Homework Assignment on Acid-Base Math:**
>
> Download the two pages of practice at www.ChemReview.Net/ABmath.PDF
>
> Answer the questions on a copy of the page *or* on your own paper. Do *not* use a calculator. Be ready for a "no-calculator" quiz on similar problems on [date].

Updates

Check back at this address (https://www.ChemReview.Net/ABMathToInstructors.PDF) on occasion for updated (and sometimes corrected…) versions – and additional materials.

Hope this helps! -- Eric Nelson

Calculator Use: What Science Says

IF you are hesitant to ask a calculator-dependent generation to solve the type of mental math problem on this practice sheet, kindly permit me to argue the following.

1. Chemistry is explained based on simple whole-number ratios. For those ratios to be simple, student mental arithmetic must be kept sharp by practice.
2. Chemistry is a quantitative science. The type of math in these problems is basic arithmetic and rules for exponentials. If students cannot solve these problems -- contrived to be solved by fundamentals of mental math -- they do not understand an essential foundation for the sciences.
3. This math is not difficult to teach and to learn. EBook lessons 1.2 to 1.4 review and if necessary teach this math as homework. Using the math in chemistry topics will help to drive both "math facts" and rules for exponentials into memory.

4. For reasons of safety, in science, medicine, and engineering, every calculation in which humans enter data into technology must be checked. Mental math estimation is one way to check a calculator answer.
5. Using mental math, students must solve in steps. If students solve a complex calculator calculation in steps, rather than by entering too much data per step as they tend to do, they are less likely to make mistakes in calculator use.
6. Here's the most important reason to teach mental math estimation. Scientists who study how the brain solves problems recommend that we

    - Teach students to *use* a calculator when the numbers are complex, but,
    - In problems designed to teach concepts, use simple numbers and ask for mental math.

    Why the difference? The brain solves problems in "working memory," for which the key rule is:

    > Working memory has limited space for information not well memorized.

    When solving a problem, working memory can apply essentially *unlimited* facts, rules, and procedures that can *quickly* be recalled from an individual's LTM, but tends to "overload" and become confused when trying to process more than a few items of information *not* quickly recallable.

    If we teach concepts with examples in which arithmetic and other needed relationships are "recallable with *automaticity*," meaning quickly and accurately, the brain is less likely to become confused. But for this to work, students must thoroughly memorize fundamentals.

    University of Virginia cognitive scientist Daniel Willingham suggests that instructors:

    > "[E]xplain to students that automaticity in facts is important because it frees their minds to think about concepts."*

Chemistry instruction is about molecules, math, and memory. By learning how science says the brain relies on memory to solve problems, we can design more effective instruction.

For additional information and references on the science of learning, see https://arxiv.org/abs/2102.00454 and https://bit.ly/2NzwrYR .

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* Willingham, D. T. Is It True That Some People Just Can't Do Math? *Am. Educ.* **2009**, *33* (4), 14-19.

Acid-Base Math Review

Do **not** use a calculator (except on question 6). Solve on a copy of this page *or* copy the question onto notebook paper. Show the steps of your work. Answers are at the end.

1. Write these fractions as decimal equivalents in the form 0.XXX (Make sure these fraction basics are well memorized.)

   a. $1/2$ = b. $\frac{1}{3}$ = c. $\frac{1.0}{4}$ = d. $\frac{1.0}{5.00}$ =

   e. $\frac{1.0}{8.0}$ = f. $\frac{1}{9}$ = g. $\frac{1.0}{20.0}$ =

2. Convert these to powers of 10 in the form 10^{x} .

   a. $\frac{10^{14}}{10^{5}}$ = b. $\frac{10^{-14}}{10^{3}}$ = c. $\frac{10^{-14}}{10^{-6}}$ =

3. Solve on a separate sheet of paper. Answer in the form 10^{x} .

   a. $(10^{-8})(10^{+3})$ = b. $(x)\,(10^{-11}) = 10^{-14}$; x = c. $(10^{-5})\,(x) = 10^{-14}$; x =

4. Change the denominator to scientific notation, then solve, then convert the answer to scientific notation. Recall that a " $\times 10^{0}$ " (= "$\times$ 1 ") can be added to place an exponential term after any number.

   a. $\frac{1.0}{0.0050} \times 10^{-14}$ =

   b. $\frac{1.0 \times 10^{0}}{0.80}$ =

   c. $\frac{1.0}{0.040}$ =

5. Solve, then convert the answer to scientific notation. (Assume an exact " 1 $\times$ " can be written in front an exponential term which has no number in front.

   a. $\frac{1.0 \times 10^{-14}}{2.0 \times 10^{-4}}$ =

   b. $\frac{1.0 \times 10^{-14}}{3.0 \times 10^{3}}$ =

   c. $\frac{10^{-14}}{0.0900}$ =

d. $\dfrac{10^{-14}}{0.0080}$ =

e. $(2.0 \times 10^{3})\ (3.5 \times 10^{-11})$ =

6. Solve on separate paper. Assume a value written as an exponential is exact.

On each problem, first write the problem with numbers rounded to the nearest whole number, solve, and convert answers to scientific notation.

Then solve again, entering the original numbers into the calculator, but solving the exponential math "in you head." Compare your two answers. Are they close?

a. $\dfrac{1.0 \times 10^{-14}}{2.8 \times 10^{-5}}$ =

b. $\dfrac{10^{-14}}{2.2}$ =

c. $(4.7 \times 10^{-2})\ (x) = 10. \times 10^{-15}$; x =

d. $(7.9 \times 10^{-7})\ (x) = 1.0 \times 10^{-14}$; x =

e. $(0.042)\ [H^{+}] = 10^{-14}$; $[H^{+}]$ =

* * * * *

ANSWERS

1a. 0.500. 1b. 0.333 1c. 0.250 1d. 0.200 1e. 0.125 1f. 0.111 1g. 0.0500 **2a.** $10^{14-5} = \mathbf{10^{9}}$

2b. $10^{-14-3} = \mathbf{10^{-17}}$ 2c. $10^{-14+6} = 10^{-8}$ **3a.** $10^{-8+3} = \mathbf{10^{-5}}$ 3b. 10^{-3} 3c. $10^{-14}/10^{-5} = 10^{-14+5} = \mathbf{10^{-9}}$

4a. $= \dfrac{1.0}{5.0 \times 10^{-3}} \times 10^{-14} = \dfrac{1}{5} \times \dfrac{10^{-14}}{10^{-3}} = 0.2 \times 10^{-14+3} = 0.2 \times 10^{-11} = \mathbf{2.0 \times 10^{-12}}$

4b. $= \dfrac{1}{8.0} \times \dfrac{10^{0}}{10^{-1}} = 0.13 \times 10^{0+1} = \mathbf{1.3 \times 10^{0}}$ 4c. $\dfrac{1 \times 10^{0}}{4.0 \times 10^{-2}} = 0.25 \times 10^{2} = \mathbf{2.5 \times 10^{1}}$

5a. $= \dfrac{1.0}{2.0} \times \dfrac{10^{-14}}{10^{-4}} = 0.5 \times 10^{-10} = \mathbf{5.0 \times 10^{-11}}$ **5b.** $= \dfrac{1.0}{3.0} \times \dfrac{10^{-14}}{10^{3}} = 0.33 \times 10^{-17} = \mathbf{3.3 \times 10^{-18}}$

5c. 1.1×10^{-13} 5d. 1.3×10^{-12} 5e. $(2.0 \times 3.5) \times (10^{3} \times 10^{-11}) = \mathbf{7.0 \times 10^{-8}}$

6a. $= \dfrac{1.0}{2.8} \times \dfrac{10^{-14}}{10^{-5}} = 0.357 \times 10^{-9} = \mathbf{3.6 \times 10^{-10}}$ Estimate = Close?

6b. $= \dfrac{1.0}{2.2} \times 10^{-14} = 0.454 \times 10^{-14} = \mathbf{4.5 \times 10^{-15}}$

6c. $x = \dfrac{10}{4.7 \times 10^{-2}} \times \dfrac{10^{-15}}{} = 2.13 \times 10^{-13} = \mathbf{2.1 \times 10^{-13}}$ Estimate = Close?

6d. $x = \dfrac{1.0 \times 10^{-14}}{7.9 \times 10^{-7}} = 0.127 \times 10^{-7} = \mathbf{1.3 \times 10^{-8}}$ 6e. $[H^{+}] = \dfrac{1 \times 10^{-14}}{4.2 \times 10^{-2}} = 0.238 \times 10^{-12} = \mathbf{2.4 \times 10^{-13}}$

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5 Minute Quiz on Acid-Base Math

Below are short quizzes on the content of the Acid-Base Math Review practice sheet. Suggested timing would be

- Assign the Acid-Base Math Review practice sheet to be completed as homework, and announce that a quiz on the practice sheet will be given in 2-3 days.
- Begin the unit on $[H^+]$ and $[OH^-]$ in strong acid and base solutions just after the quiz is given.

The announced quiz date may encourage timely homework completion.

The quiz is "no calculator." It should take 5 minutes. It is designed to be easy if students completed the homework.

There are 4 copies with simple but scrambled numbers. All 4 copies may be shuffled and handed out if security is a concern.

The quiz is intended to be closed notes and given in a class meeting when security can be maintained. If classes are all online and security is not possible, you might simply post one quiz during online class on the day the assignment is due, ask students to work on it, and then go over the answers. That's not ideal but it should help those who are willing to participate in a "self-quiz."

Answer Key

Quiz 1 (Q1 = 5.0 in denominator)

1. 2.0×10^{-7}
2. 2.5×10^{-12}
3. 1.7×10^{-10}
4. 3.3×10^{-6}

Quiz 2 (Q1 = 3.0 in denominator)

1. 3.3×10^{-6}
2. 2.0×10^{-3}
3. 1.1×10^{-9}
4. 2.5×10^{-7}

Quiz 3 (Q1 = 4.0 in denominator)

1. 2.5×10^{-10}
2. 3.3×10^{-13}
3. 1.9×10^{-14}
4. 2.0×10^{-9}

Quiz 4 (Q1 = 2.0 in denominator)

1. 5.0×10^{-9}
2. 2.5×10^{-13}
3. 1.3×10^{-12}
4. 2.0×10^{-10}

Name: _____ Section _____

Quiz On Acid-Base Math

Do *not* use a calculator. Show your work on this paper. Convert answers to scientific notation. Circle answers.

1. $\dfrac{1.0 \times 10^{-14}}{5.0 \times 10^{-8}}$ =

2. $\dfrac{1.0 \times 10^{-14}}{0.0040}$ =

3. $(2.0 \times 10^{3})\ (8.5 \times 10^{-12})$ =

4. Given: $(3.0 \times 10^{-9})\ (x) = 1.0 \times 10^{-14}$

   x =

Name: _____ Section _____

Quiz On Acid-Base Math

Do *not* use a calculator. Show your work on this paper. Convert answers to scientific notation. Circle answers.

1. $\dfrac{1.0 \times 10^{-14}}{3.0 \times 10^{-9}}$ =

2. $\dfrac{1.0 \times 10^{-14}}{0.0050}$ =

3. $(2.0 \times 10^{3})\ (5.5 \times 10^{-11})$ =

4. Given: $(4.0 \times 10^{-8})\ (x) = 1.0 \times 10^{-14}$

   x =

Name: _____ Section _____

Quiz On Acid-Base Math

Do *not* use a calculator. Show your work on this paper. Convert answers to scientific notation. Circle answers.

1. $\dfrac{1.0 \times 10^{-14}}{4.0 \times 10^{-5}}$ =

2. $\dfrac{1.0 \times 10^{-14}}{0.030}$ =

3. $(2.0 \times 10^{3})\ (9.5 \times 10^{-18})$ =

4. Given: $(5.0 \times 10^{-6})\ (x) = 1.0 \times 10^{-14}$

   x =

Name: _____ Section _____

Quiz On Acid-Base Math

Do *not* use a calculator. Show your work on this paper. Convert answers to scientific notation. Circle answers.

1. $\dfrac{1.0 \times 10^{-14}}{2.0 \times 10^{-6}}$ =

2. $\dfrac{1.0 \times 10^{-14}}{0.040}$ =

3. $(2.0 \times 10^{3})\ (6.5 \times 10^{-16})$ =

4. Given: $(5.0 \times 10^{-5})\ (x) = 1.0 \times 10^{-14}$

   x =