Toolbox (Foundational Concepts)

Chapter Summary:

This chapter will focus on foundational concepts and skills you will use throughout this study guide and likely on your exam. This should not be considered a comprehensive list of preparatory material, but does include important concepts that will be referenced in the content chapters.

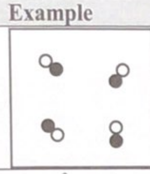
Specific topics covered in this chapter are:

- Unit conversations
- Significant figures
- Scientific notation
- Nomenclature
- Density
- Classification of matter
- Properties and representations of matter

Additionally, this chapter will include supplemental information in sections at the end of this chapter for preparation for your exam including:

- Sample instructions
- Sample datasheet
- How to use this book

Common representations used in questions related to this material:

Name	Example	Used in questions related to
Particulate representations		Classification of matter
Compound units	$g \cdot cm^{-3}$	Density or unit conversion

Where to find this in your textbook:

The material in this chapter typically aligns to an introductory chapter or chapters (could be labeled as "Matter and Measurement" or "Atoms, Molecules, and Compounds") in your textbook. The name of your chapter may vary.

Practice exam:

There are practice exam questions aligned to the material in this chapter. Because there are a limited number of questions on the practice exam, a review of the breadth of the material in this chapter is advised in preparation for your exam.

How this fits into the big picture:

The material in this chapter aligns to the Big Idea of Experiments, Measurement and Data (9) as listed on page 12 of this study guide.

Study Questions (SQ)

SQ-1. Plank's constant is 6.626×10^{-34} J·s. What is this value in kJ·µs?

(A) 6.626×10^{-40} kJ·µs

(B) 6.626×10^{-37} kJ·µs

(C) 6.626×10^{-34} kJ·µs

(D) 6.626×10^{-31} kJ·µs

Knowledge Required: (1) Definitions of metric prefixes.

Thinking it Through: As you read this question, you see that the units for the value are given with no prefixes: "J" and "s". The units to which you are converting are prefixed: "kJ" and "μs". Therefore, you could start this question by reviewing your metric prefixes (a good idea during studying as well):

Prefix	Name	Value
M	mega	10^6 or 1,000,000
k	kilo	10^3 or 1,000

Prefix	Name	Value
c	centi	10^{-2} or 0.01
m	milli	10^{-3} or 0.001
μ	micro	10^{-6} or 0.000001
n	nano	10^{-9} or 0.000000001
p	pico	10^{-12} or 0.000000000001

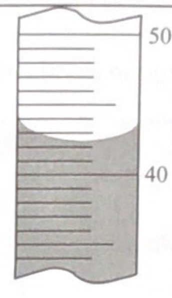
You can then see that you will use the equivalencies of 1 kJ = 1000 J and 1 μs = 10^{-6} s and then use this to convert the value:

$$\left(6.626\times10^{-34}\ \text{J}\cdot\text{s}\right)\left(\frac{1\ \text{kJ}}{1000\ \text{J}}\right)\left(\frac{1\ \mu\text{s}}{10^{-6}\ \text{s}}\right)=6.626\times10^{-31}\ \text{kJ}\cdot\mu\text{s or choice } \mathbf{(D)}$$

Choice **(A)** incorrectly defines micro as 10^{-3} and inverts the conversion. Choice **(B)** inverts the conversion of seconds only and Choice **(C)** incorrectly defines micro as 10^{-3}.

Practice Questions Related to This: **PQ-1** and **PQ-2**

SQ-2. What is the reading on this graduated cylinder to the correct number of significant figures?



(A) 42 mL

(B) 42.5 mL

(C) 42.50 mL

(D) 44 mL

Knowledge Required: (1) Significant figures. (2) Reading a meniscus.

Thinking it Through: This question helps remind you that the rules for significant figures are in place because of measurements that are made. This example uses a graduated cylinder. Before you can determine the number of significant figures you will have in your answer, you first recall that you will read the bottom of the meniscus as shown to the right:

Now you can determine the value. You start with the largest increment (measured by 1 mL increments), and see that the meniscus is halfway between the 42nd and 43rd mL (so the value will be 42 mL as a start). Now you observe that the meniscus is halfway between 42 and 43, giving you 42.5 mL. Finally, because you estimated the last significant figure (5), the measurement of 42.5 mL or choice **(B)** is correct.

Choices **(A)** and **(C)** do not use the correct number of significant figures based on the increments available to you and choice **(D)** is not correct as this uses the incorrect location of reading the meniscus.

Practice Questions Related to This: **PQ-3** and **PQ-4**

SQ-3. Which compound is named correctly?

(A) $FeCO_3$, iron carbonate

(B) K_2SO_3, potassium sulfite

(C) $Sr(NO_3)_2$, strontium nitrite

(D) $Co_2(SO_4)_3$, cobalt(II) sulfate

Knowledge Required: (1) Rules for nomenclature. (2) Formula and names of polyatomic ions.

Thinking it Through: The question tells you that you are going to be using the rules of nomenclature (or naming) to answer this. When you skim the choices, you can see that this question is about ionic nomenclature. Therefore, you know the general rules for ionic nomenclature are:

1. Name the metal or polyatomic cation first (first word for simple compounds).
    a. For those metals with only one cationic charge (such as most of the main group metals), you use just the name of the metal. For example, Na^+ would be "sodium" and Zn^{2+} would be "zinc".
    b. For those metals with more than one cationic charge (such as most of the transition metals), you would use the name of the metal followed by the charge in Roman numerals in parentheses. For example, Fe^{3+} would be "iron(III)" and Pb^{2+} would be "lead(II)".
    c. Polyatomic cations are named with the name of the cation.
2. Name the nonmetal or polyatomic anion second (second word for simple compounds).
    a. For monatomic anions, this is the stem of the element plus the suffix "-ide". For example, S^{2-} is "sulfide" and O^{2-} is "oxide".
    b. Polyatomic anions are named with the name of the anion.

Additionally, for this question, you also need to know the names and formula of polyatomic anions:

CO_3^{2-} = carbonate SO_3^{2-} = sulfite NO_3^- = nitrate SO_4^{2-} = sulfate

Finally, to give the charge for the metals that require them, you will also need to know the charge on the metal. You do this using charge balance of the compound. Algorithmically, this is commonly done through the "cross down" method or the subscript in the formula is the opposite charge on the ion (making sure to still check once you use this that your formula is represented correctly; i.e. it is an empirical formula with the correct ratio of cation:anion; also make sure you understand *why* this method works):

$$Fe^{3+} \quad O^{2-}$$
$$Fe_2O_3$$

Therefore, combining all of these, choice **(B)** does not need a charge on the metal (potassium has only one charge, +1), sulfite is named correctly and the ratio for charge balance is correct.

Choice **(A)** is missing the charge (should be II). Choice **(D)** has a charge, but it is the wrong charge (should be III not II). Finally, choice **(C)** has the wrong name of the polyatomic anion.

Practice Questions Related to This: **PQ-5, PQ-6,** and **PQ-7**

SQ-4. In the name arsenic trichloride, the *tri-* prefix specifies

Conceptual

(A) arsenic has an oxidation state of +3.

(B) the geometry of the molecule is trigonal pyramidal.

(C) arsenic is covalently bonded to three chlorine atoms.

(D) arsenic(III) is ionically bonded to three chloride ions.

Knowledge Required: (1) Rules for nomenclature.

Thinking it Through: The question tells you that you are going to be using the rules of nomenclature again to answer this. From the question, you can see this is about molecular nomenclature (or naming molecules or covalent compounds). Therefore, you know the general rules for covalent nomenclature are (for simple compounds):

1. Name the first element shown in the formula first (first word in the name).
   This name is the name of the element with the prefix for the number of atoms of the element using Greek prefixes:

number	prefix	number	prefix
1	mono-	6	hexa-
2	di-	7	hepta-

number	prefix	number	prefix
3	tri-	8	octa-
4	tetra-	9	nona-
5	penta-	10	deca-

When there is only one atom of the element, the prefix of "mono-" is not used. For example, $\underline{N_2}O_4$ is "dinitrogen" and $\underline{C}O$ is simply "carbon".

2. Name the second element shown in the formula second (second word in the name). This name is the name of the stem of the element with the prefix for the number of atoms of the element using Greek prefixes for all numbers of atoms including one and the suffix "-ide". When two vowels are adjacent that are either o or a, the letter of the prefix is omitted. For example, $N_2\underline{\mathbf{O_4}}$ is "tetroxide" and $C\underline{O}$ is "monoxide".

Choice **(C)** reflects the correct usage of the Greek prefix (and the formula of arsenic trichloride, $AsCl_3$, reflects this).

Choice **(A)** incorrectly links the prefix of "tri" to oxidation state. Choice **(D)** implies this is an ionic compound, which is not correct. No structural information is provided with this name, so choice **(B)** is not correct either.

Practice Questions Related to This: **PQ-8** and **PQ-9**

SQ-5. What is the formula of iodic acid?

(A) HIO **(B)** HIO_2 **(C)** HIO_3 **(D)** HIO_4

Knowledge Required: (1) Rules for nomenclature. (2) Formula and names of polyatomic ions.

Thinking it Through: The question tells you that you are going to be using the rules of nomenclature (or naming) for acids to answer this. Therefore, you know the general rules for naming acids are based on the type of acid:

Binary acids – those with hydrogen and a monatomic anion:

First word: hydro + the stem of the anion + ic

Second word: acid

Ex: HI = hydro + iod + ic acid = hydroiodic acid

Oxoacids – those with hydrogen and a polyatomic anion:

First word: if the anion has the suffix "-ite" then remove the "-ite" and add "-ous"

Ex: the nitri**<u>te</u>** ion, NO_2^-, becomes nitr**<u>ous</u>**

if the anion has the suffix "-ate" then remove the "-ate" and add "-ic"

Ex: the nitr**<u>ate</u>** ion, NO_3^-, becomes nitr**<u>ic</u>**

Second word: acid

Ex: HNO_2 = nitrous acid HNO_3 = nitric acid

Working backwards, iodic acid means this is the acid with iodate ion or IO_3^-. Therefore, the acid formula is HIO_3 or choice **(C)**. Choice **(A)** is hypoiodous acid; choice **(B)** is iodous acid; and choice **(D)** is periodic acid.

Practice Questions Related to This: **PQ-10** and **PQ-11**

SQ-6. Twenty irregular pieces of an unknown metal have a collective mass of 28.225 g. When carefully placed in a graduated cylinder that originally contained 7.75 mL of water, the final volume read 11.70 mL. What is the density of the metal (in $g{\cdot}cm^{-3}$)?

(A) $2.41\ g{\cdot}cm^{-3}$ **(B)** $3.64\ g{\cdot}cm^{-3}$ **(C)** $7.15\ g{\cdot}cm^{-3}$ **(D)** $112\ g{\cdot}cm^{-3}$

Knowledge Required: (1) Definition of density. (2) Displacement.

Thinking it Through: As you read this question, you recognize that you will need to calculate the density of the metal which you know is the mass of the substance divided by the volume it occupies. You are given the mass in the problem, so you will need to use the information provided to determine the volume. The volume of the metal is determined by displacement of water:

$$V_{\text{f, water + metal}} - V_{\text{i, water}} = V_{\text{metal}} \text{ or } 11.70 \text{ mL} - 7.75 \text{ mL} = 3.95 \text{ mL}$$

Therefore, you can calculate the density of the metal (and convert from mL to cm^3):

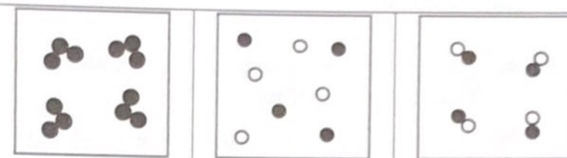
$$\left(\frac{28.225 \text{ g}}{3.95 \text{ mL}}\right)\left(\frac{1 \text{ mL}}{1 \text{ cm}^3}\right) = 7.15 \text{ g}\cdot\text{cm}^{-3} \text{ which is choice } \textbf{(C)}$$

Choice **(A)** uses the final volume of water and metal and choice **(B)** uses the initial volume of only the water. Choice **(D)** uses the correct volume of the metal but then calculates the density incorrectly by multiplying the mass and volume.

Practice Questions Related to This: **PQ-12** and **PQ-13**

SQ-7. Conceptual

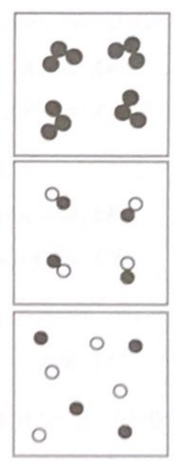
What are the correct classifications for **I**, **II**, and **III**?



I **II** **III**

	I	II	III
(A)	element	compound	mixture
(B)	element	mixture	compound
(C)	compound	mixture	element
(D)	mixture	element	compound

Knowledge Required: (1) Classification of matter/definitions. (2) Particulate diagrams.



Thinking it Through: As you read through this and evaluate the diagrams, you realize that you need to use your definitions of element, compound and mixtures.

First, you know that an element is a group of atoms with the same or similar properties. Merging this with the diagrams you are provided, you see that you are looking for one atom type only which would be sample **I**.

Second, you know that a compound is a pure substance which contains two or more elements chemically combined (or bonded together). Bonded atoms are shown in diagrams **I** and **III**, where the bonded atoms in diagram I are all the same type (so showing a molecular *element*) where diagram **III** is showing bonded atoms of different types (so showing a molecular *compound*); **III** is the compound.

Finally, a mixture is two or more pure substances physically combined. Sample II shows two different atom types mixed together and not bonded together, so this is the mixture of two elements.

These combine to the correct choice of **(B)**.

Practice Questions Related to This: **PQ-14** and **PQ-15**

Practice Questions (PQ)

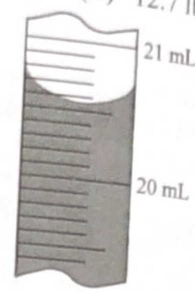
PQ-1. The speed of light is 3.0×10^{8} m·s^{-1}. What is this speed in nm·ms^{-1}?

(A) 3.0×10^{-4} nm·ms^{-1} **(B)** 3.0×10^{2} nm·ms^{-1} **(C)** 3.0×10^{14} nm·ms^{-1} **(D)** 3.0×10^{20} nm·ms^{-1}

PQ-2. The density of helium is 0.164 kg·m^{-3}. What is this density in lb·ft^{-3}? 1 kg = 2.20 lb and 1 m = 3.28 ft

(A) 0.0102 lb·ft^{-3} **(B)** 0.110 lb·ft^{-3} **(C)** 1.18 lb·ft^{-3} **(D)** 12.7 lb·ft^{-3}

PQ-3. Based on the figure, what volume should be reported for the liquid?



(A) 20.8 mL

(B) 20.68 mL

(C) 20.6 mL

(D) 20.57 mL

PQ-4. What is the correctly reported mass of water based on the data in the table?

Mass of beaker and water	29.62 g
Mass of beaker only	28.3220 g

(A) 1.3 g **(B)** 1.30 g **(C)** 1.298 g **(D)** 1.2980 g

PQ-5. What is the name of $Ti_3(PO_4)_4$?

(A) titanium phosphate **(B)** titanium(III) phosphate

(C) titanium(IV) phosphate **(D)** titanium tetraphosphate

PQ-6. The formula of strontium hexafluorosilicate is $SrSiF_6$. What is the formula of aluminum hexafluorosilicate?

(A) $AlSiF_6$ **(B)** $Al_2(SiF_6)_3$ **(C)** Al_3SiF_6 **(D)** $Al_3(SiF_6)_2$

PQ-7. Which is <u>**NOT**</u> named correctly?

(A) MnO_2 manganese(II) oxide **(B)** $CuSO_4$ copper(II) sulfate

(C) Na_3PO_4 sodium phosphate **(D)** CaF_2 calcium fluoride

PQ-8. What is the correct name for N_2O_5?

(A) nitrogen(II) oxide **(B)** nitrogen(V) oxide

(C) dinitrogen oxide **(D)** dinitrogen pentoxide

PQ-9. What is the formula of sulfur trioxide?

(A) SO_2 **(B)** SO_3 **(C)** SO_3^{2-} **(D)** SO_4^{2-}

PQ-10. What is the name of $HBrO_4(aq)$?

(A) bromic acid **(B)** bromous acid **(C)** hydrobromic acid **(D)** perbromic acid

PQ-11. What is the formula of hydroiodic acid?

(A) HI(aq) **(B)** HIO(aq) **(C)** HIO_2(aq) **(D)** HIO_3(aq)

PQ-12. If a palladium nanoparticle has a density of 12.0 $g{\cdot}cm^{-3}$, what is the mass of a nanoparticle with a volume of $1.84{\times}10^{-21}$ cm^3?

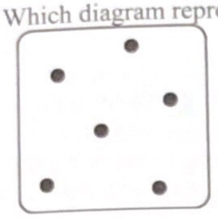
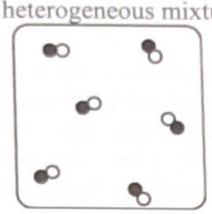
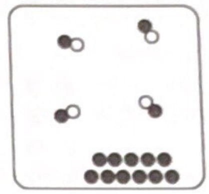
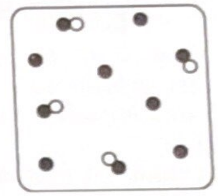
(A) $2.21{\times}10^{-20}$ g **(B)** $1.63{\times}10^{-20}$ g **(C)** $6.52{\times}10^{-21}$ g **(D)** $1.53{\times}10^{-22}$ g

Conceptual **PQ-13.** Which sample has the largest volume?

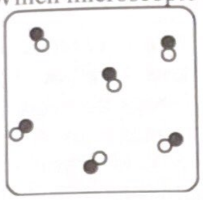
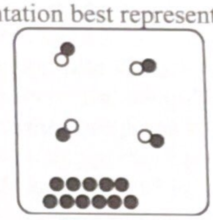
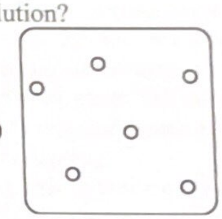
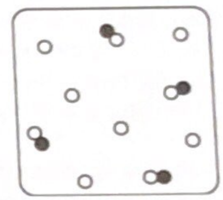
Densities	
aluminum 2.7 $g{\cdot}cm^{-3}$	copper 9.0 $g{\cdot}cm^{-3}$

(A) 1.0 g aluminum **(B)** 5.0 g aluminum **(C)** 1.0 g copper **(D)** 5.0 g copper

Conceptual **PQ-14.** Which diagram represents a heterogeneous mixture?

(A)  **(B)**  **(C)**  **(D)** 

Conceptual **PQ-15.** Which microscopic representation best represents a solution?

(A)  **(B)**  **(C)**  **(D)** 

Answers to Study Questions

1. D
2. B
3. B
4. C
5. C
6. C
7. B

Answers to Practice Questions

1. C
2. A
3. D
4. B
5. C
6. B
7. A
8. D
9. B
10. D
11. A
12. A
13. B
14. C
15. D

How to use this book

You have an ACS exam coming up and might be feeling a bit overwhelmed by it. You might be worried that the exam will be very different from the ones you are used to and will be on material you haven't covered. The first thing to do is to R-E-L-A-X. The ACS exam you are going to take was written by chemistry faculty from around the country who all teach general chemistry courses. The truth is that most general chemistry courses, like most general chemistry textbooks, are very similar. There is a set of common topics that almost every course covers. What makes courses different are the level of detail of coverage of the topics. Some instructors have favorite topics that they cover in depth and some that they only briefly cover due to time. The good news is that the exam you are going to take was written to be applicable to this wide variety of topic coverage and depth of topic coverage. The committees that write these exams do not look for the most minute details; instead the topics covered are the foundational ones that are common to most courses, and you should recognize them. Due to the variations in courses, described above, you might see a few questions about topics that are not as familiar to you. That is fine, relax!

As you use this study guide, and study chemistry in general, you should focus on the underlying concepts present in a question. Remember that there are many ways to ask a question about stoichiometry (conservation of matter). If you focus on identifying the underlying concept/topic being asked about in the question, you will be able to handle any "surface" differences in the way the question is asked. After you complete a problem, and before you go onto the next question, take a minute to think about other ways the problem could have been asked. For example, what if you had been given the information in the answer and had been asked for some information that was given to you in the original question? When you stop and think like this, you have moved beyond working problems to actual studying.

The chapters in this study guide are arranged in the same order as many common chemistry textbooks. Topics typically covered in the first semester are in chapters (1–8) and typical second semester topics are in chapters (9–16). Each chapter begins with a brief summary and a list of topics covered. This list of topics should correspond to the topics covered in your course. Because chemistry relies on many different types of representations, the types of representations/notations used in the chapter are previewed. Following this you will be told where the material might be found in your chemistry textbook. There is not much variation in chapter titles between books, so you should be able to find the relevant material no matter what book you have. This is an important point; this study guide is not intended to be a replacement for your textbook. It is a supplement specifically designed to assist you to prepare for the ACS exam. The introductory material ends with a mention of online practice exam problems and how the material in the chapter fits into the bigger picture of chemistry concepts.

Following this introductory material, you will find worked Study Questions. The best way to use these would be to cover up the detailed solution and try to answer the question/work the problem. Only after you have tried the question should you move to the discussion of the solution. The worked-out solution is written to model the thinking that could be used to answer the question correctly. Sometimes, this involves solving the problem without looking at the multiple-choice options (i.e., numerical problems), other times this involves an analysis of each choice (i.e., selecting a correct statement). At the end of each study question, you will find an explanation of why each incorrect choice is wrong and which practice problems at the end of the chapter correspond to the study question. There are as many as 30 practice problems at the end of each chapter.

Some study questions and practice problems are marked as **Conceptual** using a special notation next to the problem number. We specifically included this because part, half or possibly all of your ACS Exam will have conceptual problems. These types of questions can also test your deeper understanding of a concept and can be useful gauges of how well you understand the material. Often, these questions do not require detailed calculations, instead these can involve interpreting particulate nature of matter representations and/or graphical information, among other things.

Remember that this study guide was written to give you practice with ACS exam-type questions as you review the chemistry content. As you review, you are likely to find topics that you need to go back to your textbook and notes to review and you will find some topics that you have a very good grasp of. Don't let the thought of a BIG ACS exam scare you; if you have been working throughout the course and put in some quality study time, you will be fine!