Chemistry Card Games

Games for Learning and Enjoying Chemistry

Michelle Clark, M.S.
Joan A. Cotter, Ph.D.

ABOUT THE AUTHORS

Michelle Clark has a Bachelor of Science in chemistry from Arizona State University and a Master of Science in medicinal chemistry and molecular pharmacology from Purdue University. She has taught chemistry at Johnson County Community College in Kansas for 18 years. Michelle developed a chemistry preparation course for students who had never taken high school chemistry or had been unsuccessful in previous chemistry courses. During her 18 years of teaching, she noticed that for many students who struggled with chemistry, they struggled even more with the math.

Michelle's two children use the *RightStart™ Mathematics* program. The Clark family loved the engaging and effective curriculum. This gave Michelle the idea to collaborate with Activities for Learning, Inc for teaching the math and some basic chemistry facts through playing games. This proposal developed into a sabbatical project generously supported by Johnson County Community College.

Joan A. Cotter Ph. D. has a degree in electrical engineering from the University of Wisconsin-Madison and a doctorate in mathematics education from the University of Minnesota. She has taught ages 3–6 as a Montessori teacher, taught grades 6–8 as a mathematics teacher, and tutored students with special needs. She presents at conferences worldwide.

Joan designed the double-sided AL Abacus and wrote the preschool to eighth grade *RightStart™ Mathematics* and *RightStart™ Mathematics*, second edition, programs along with the *RightStart™ Tutoring* series.

The authors are extremely grateful to Constance Cotter's contributions. This book would be a fraction of its current state without her valuable feedback and willingness to play every single game in this book!!

Copies may be ordered from:

Activities for Learning, Inc.
321 Hill Street
Hazelton, ND 58544-0468
U.S.A.

888-272-3291 or 701.782-2000

order@RightStartMath.com
www.RightStartMath.com

Printed in the United States of America
September 2021

ISBN: 978-1-942943-47-1

TABLE OF CONTENTS

How to use the *Chemistry Card Games* manual

Where to begin? Here are some pointers to help you maximize the amazing learning tool you have in your hands.

1. This manual is divided into five sections: Unit Conversion, Density, Periodic Table, Ionic Compounds, and Concentration.

2. Each chapter begins with the easiest game on that topic then gets increasingly challenging as the chapter progresses.

3. When trying to understand a game's instructions, have the required cards *in your hands*. It is much easier to understand how the games work if you are holding the cards instead of imagining what to do. These games were written with the cards right beside us.

4. Read the games' objectives. This will help you identify which game is best for a topic or need. You will find various games with the same objective. These games provide the students variety while they continue to work on a skill or concept. Playing games more than once enables a more thorough understanding.

5. Make notes as to what games were played when, by whom, and whether it was enjoyed or not. Make general notes next to the game right in this manual, which will help you as follows.

   First, fun and easy games are quickly identified and can be reviewed on more challenging days.

   Second, it will help identify games that are found to be challenging, whether the games were difficult because the player wasn't ready for the game, was having a rough day in general, or doesn't like that type of game.

6. If you have questions on how to play a game, please call 888-272-3291 and one of our helpful customer service representatives will be delighted to assist you.

Enjoy this book. Keep it around for years to have fun with chemistry. Have a great day and play a chemistry card game!

Michelle Clark, M.S. *Joan A. Cotter, Ph.D.* *Constance Cotter*
and the Activities for Learning, Inc team

INTRODUCTION

Math literacy is fundamental to student success in chemistry courses. Research demonstrates that student difficulties in chemistry do not arise from the application of math to chemistry, but rather the students' underlying mathematical deficits before enrolling in chemistry. In other words, without a good mathematics foundation, many students find chemistry challenging to learn.

Most chemistry courses begin with unit conversion, also known as dimensional analysis. A solid understanding of fractions is required to convert units. Chemistry students of all ages benefit from a review of basic mathematical operations, as well as a reframing of math itself. Fresh and fun games enable these students not only to succeed with the mathematics in chemistry, but also to enjoy using math to solve chemistry problems.

Activities for Learning, Inc. teaches strong mathematical foundations in a fun and inviting way with the *RightStart™ Mathematics* curriculum. *RightStart™ Mathematics* has earned many awards over the years as well as the respect of many in the mathematics field. *Chemistry Card Games* was created using many of the same underlying foundational concepts found in *Math Card Games*, the games used in the *RightStart™ Mathematics* curriculum.

WHY PLAY CHEMISTRY CARD GAMES

There is evidence suggesting positive emotions are tied to better learning and retention. Chemistry games provide a much-needed opportunity for students to play with other students learning the same material.

Playing chemistry games together enables students to learn, laugh, and see each other as teammates. Learning through these games helps all students, especially those who may have some apprehension and anxiety early on in chemistry courses. Frequently, chemistry classes are prerequisites for challenging programs, such as nursing, chemical engineering, premed, pre-dental, or pre-veterinary.

Additionally, playing chemistry games removes the assessment or judgment piece that students typically associate with chemistry classes. The games are not quizzes or exams. They are not to be confused with flashcards, which offer only one level of learning — memorization. Flashcards fall short when application of principles is required. Thus, *Chemistry Card Games* provides opportunities to encourage cooperation and enhance learning.

PLAYING THE GAMES

This manual can be used with any beginning chemistry program. These games provide a way to help students needing remediation or enrichment. It is recommended to play the games in order as concepts build on each other. Some games need to be played more than once to achieve the objective.

Who can play

Anyone can play these games.

You need not be competent in chemistry to play these games. Anyone with the most basic arithmetic skills can do it. Algebra is not a prerequisite for this book; even if you have math anxiety, you will most likely enjoy this approach. It is our hope that after playing a few of the games you will start to enjoy math and chemistry too.

What is taught

There are five sections: Unit Conversion, Density, Periodic Table, Ionic Compounds, and Concentration. Within each chapter the beginning games are easy and gradually become harder. The final games in each chapter teach the more advanced concepts.

It is not necessary to complete each chapter before starting another chapter. Games in later chapters can be played concurrently with earlier games, although the later games often build on a concept introduced earlier. Generally, it is recommended to play the games in order.

What age

Players of any age with some familiarity of the periodic table, multiplication, division, and basic fractions can play. Start with an easy game to check skills and build confidence. The level of difficulty can be determined by the objective. If a game is found to be too hard, try a different game found earlier in the chapter.

For middle school and high school students, the recommended order is as follows:

- Periodic Table (complete chapter)
- Ionic Compounds (games 1 to 12)
- Unit Conversion (games 1 to 19 and for advanced students, the complete section)
- Density (games 1 to 10 and for advanced students, the complete section)
- Concentration (mainly for advanced students).

In the classroom

These games offer opportunities for active learning in the classroom following lectures covering these concepts. For example, after covering unit conversion, students can play a game. Enjoy the laughter that occurs while students gain confidence and enjoy learning chemistry.

DESCRIPTION OF THE CARDS

To play these games, nine special decks of cards are needed. These cards are available from Activities for Learning, Inc. The descriptions are below.

The # sign in the column shows the quantity of cards of that particular numerical quantity.

Reading the numerical quantities horizontally across the rows gives equivalent quantities, considering significant figures. The highlighted row on the Length deck table shows 0.006 km = 6 m = 600 cm. These tables can act as solution keys to games throughout the manual.

Length Cards

The Length cards consist of 64 cards with different units of miles, kilometers, meters, and centimeters. The table on the right lists each card with its numerical quantity and unit.

The reverse side of the Length cards shows a platinum-iridium meter standard. The shape of the standard with the X-shaped cross section was useful in preventing distortions. Currently, the meter is defined using the speed of light in a vacuum.

Length Deck — 64 cards

Increasing Length ↓

mi	#	km	#	m	#	cm	#
				0.040	2	4	2
				0.050	2	5	2
				0.060	2	6	2
		0.001	1	1	2	100	1
		0.002	1	2	2	200	1
		0.003	1	3	2	300	1
		0.004	1	4	2	400	1
		0.005	1	5	2	500	1
		0.006	1	6	2	600	1
3	2	5	1	5000	1		
24	2	39	2				
28	2	45	2				
37	2	60	2				
43	2	69	2				
55	2	88	2				
75	2	120	2				

# indicates number of cards

Volume Cards

The Volume deck consists of 64 cards with units of liters, milliliters, cubic centimeters, fluid ounces, tablespoons, and teaspoons.

The reverse side of the Volume cards shows a volumetric flask that is used to prepare solutions.

Volume Deck — 64 cards

Increasing Volume ↓

L	#	mL	#	cm^3	#	fl. oz.	#	tbsp	#	tsp	#
0.001	1	1	2	1	1						
0.002	1	2	2	2	1						
0.003	1	3	2	3	1						
0.004	1	4	2	4	1						
0.005	1	5	1	5	2					1	2
0.006	1	6	2	6	1						
0.008	2	8	1	8	1						
0.010	2	10	1	10	1						
0.012	2	12	2								
		15	2					1	1	3	1
0.020	1	20	2	20	1						
0.030	1	30	2			1	1	2	2		
0.040	2	40	1	40	1						
0.100	2	100	2								
0.200	2	200	2								

# indicates number of cards

Mass Cards

The Mass deck consists of 64 cards with different units of kilograms, grams, milligrams, pounds, and ounces.

The reverse side of the Mass cards shows a mass standard that ensures balances are calibrated correctly.

Mass Deck — 64 cards

kg	#	g	#	mg	#	lb	#	oz	#
		2	2	2000	2				
		3	2	3000	2				
0.005	1	5	2	5000	1				
0.008	1	8	2	8000	1				
0.012	1	12	2	12000	1				
0.015	1	15	2	15000	1				
0.016	1	16	2	16000	1				
0.020	1	20	2	20000	1				
0.024	1	24	2	24000	1				
0.028	1	28	2					1	1
0.030	2	30	2						
0.036	2	36	2						
0.048	2	48	2						
0.060	2	60	2						
						0.25	2	4	2
0.454	1	454	1			1	1	16	1

Increasing Mass ↓

# indicates number of cards

Time Cards

The Time deck consists of 22 cards with units of minutes, hours, days, weeks, and years.

The reverse side of the Time cards shows clocks featuring the Droste effect, famously used by artist M. C. Escher.

Time Deck — 22 cards

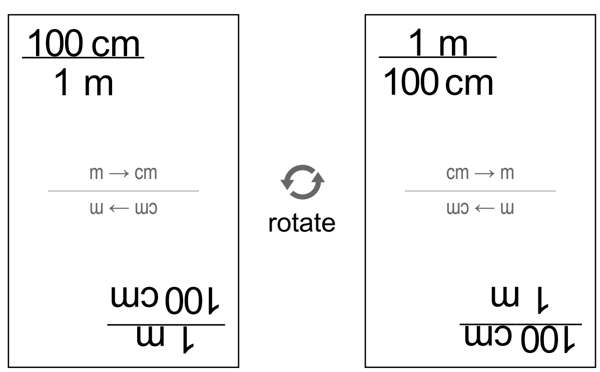
min	#	hour	#	day	#	week	#	year	#
5	2								
10	2								
15	2	0.25	2						
30	2								
60	2	1	2						
		24	2	1	2				
						1	2		
								1	2

# indicates number of cards

Conversion Cards

The Conversion deck consists of 86 cards with a variety of units that can be used to convert one unit of measurement to another. See the example on the right. This card can be used to convert liters to milliliters or milliliters to liters depending on which way the card is oriented.

Conversion factors can be generated from equivalent amounts, such as 100 cm = 1 m. Additionally, conversion factors can be generated from a density or concentration that is unique to each substance.



The card on the left can be used to convert m to cm. When this card is rotated, the conversion factor on the top is used to convert cm to m.

There are two types of Conversion cards. Type 1 is equivalents, such as 100 cm = 1 m and 1 in = 2.54 cm. Type 2 occurs from a given situation, such as, I am bicycling 10 miles per hour (10 mi/h) or density, such as water has a density of 1 g/mL or copper has a density of 9 g/cm^3.

All of these Conversion cards can be rotated so the both relationships are visible and available for use. For example, the 10 mi/h Conversion card has both 10 mi/h and 1 h/10 mi printed one each side, equal and different ways of saying the same speed.

The Conversion deck consists of these two types of factors. For equivalent amounts, the card will have an arrow in the center, for example, m → cm. The center of the card specifies densities, concentrations, or speeds.

The reverse side of the Conversion cards shows the different International System of Units (SI) units. The units shown on the wheel are mass (kg, kilogram), length (m, meter), electric current (A, ampere), temperature (K, kelvin), amount of substance (mol, mole), and luminous intensity (cd, candela).

Conversion Deck — 86 cards

Type 1 Equivalent Amounts 33 cards

Length	#	Volume	#
1 m = 100 cm	3	1 L = 1000 mL	3
1 km = 1000 m	2	1 gal = 128 fl oz	1
1 mi = 5280 ft	1	1 gal = 8 pt	1
1 in = 2.54 cm	1	1 gal = 4 qt	1
1 mi = 1.609 km	1	1 tsp = 5 mL	1
1 m = 39.37 in	1	1 tbsp = 15 mL	1
Time	**#**	1 L = 1.057 qt	1
1 min = 60 s	1	**Mass**	**#**
1 h = 60 min	1	1 g = 1000 mg	3
1 h = 3600 s	1	1 kg = 1000 g	3
1 d = 24 h	1	1 lb = 454 g	1
1 wk = 7 d	1	1 lb = 16 oz	1
1 yr = 52 wk	1	1 kg = 2.205 lb	1

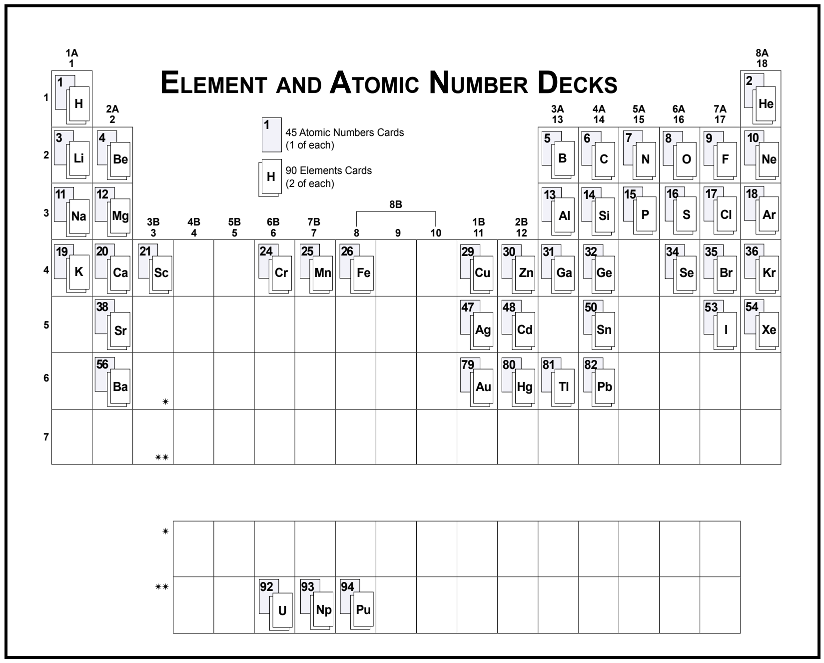
Type 2 One of each the cards listed below 53 cards

Density g/mL	Density g/cm^3	Density kg/L	Concentration mol/L	Speed mi/h
0.5	0.5	0.5	0.5	10
1	1	1	1	
1.5	1.5	1.5	1.5	
2	2	2	2	
3	3	3	3	
5	5	5	5	
6	6	6	6	
8	8	8	8	
9	9	9	9	
10	10	10	10	
12	12	12	12	
15	15	15	15	
20	20	20	20	

Element Cards

The Element deck consists of two sets of 45 cards plus the key card, for a total 91 cards. The key identifies what color corresponds to each group within the periodic table.

The reverse side of the Element cards shows a color coded periodic table. The element symbol colors correspond to the different groups and classifications on the periodic table.



Atomic Number Cards

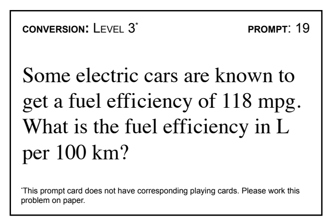
The Atomic Number deck consists of 45 cards corresponding to the Element cards.

The reverse side of the Atomic Number cards shows the line spectra for hydrogen, helium, and oxygen. Like a person's fingerprint, the line spectra are unique to each element.

Henry Moseley discovered the line spectra were connected to the atomic number of each element. This discovery led to the arrangement of the periodic table by atomic number (number of protons) instead of atomic weight.

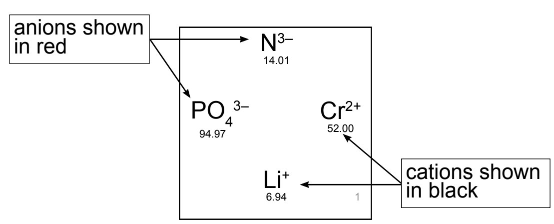
Prompt Cards

The Prompt deck consists of 29 cards with different types of word problems covering density, unit conversion, and concentration. Level 1 problems are the easiest, while Level 3 are the hardest. Levels 1 and 2 have playing cards with quantities corresponding to the amounts listed on the prompt cards. An asterisk, *, in the top line of a card as shown on the right, indicates that not all of the corresponding playing cards are available.



Compound Corner Cards

Each card has two cations (pronounced CAT-eye-ons) in black and two anions (pronounced AN-eye-ons) in red. The molar mass is listed below each cation and anion. The cations contain main group metals, transition metals, and ammonium ion. The anions contain nonmetal ions and a range of polyatomic ions. There are 30 unique Compound Corner cards. The small gray number in the lower right is used solely to keep track of the cards.



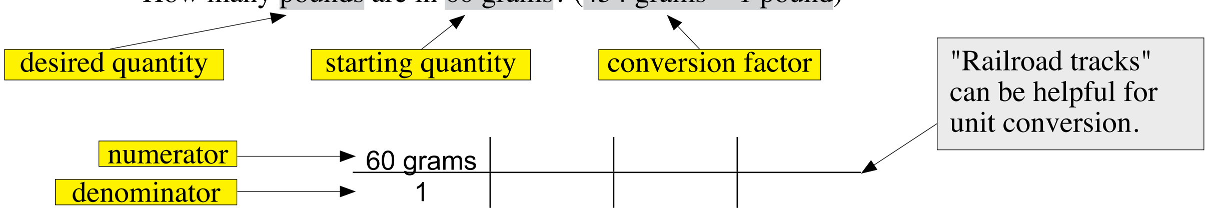
UNIT CONVERSION (UC)

For many students, unit conversion can be very challenging. This does not have to be the case! When unit conversion is viewed as “canceling out” units in the numerator and denominator, the process can be greatly simplified.

To make the conversion process easier, begin by writing the starting quantity on the left side of the paper with a line underneath it and the number one below (as long as the starting quantity has only one unit). This creates a clear delineation of the numerator and denominator from the beginning. The table is sometimes referred to as “Railroad Tracks.” Additionally, setting up a table or grid can assist the unit conversion process.

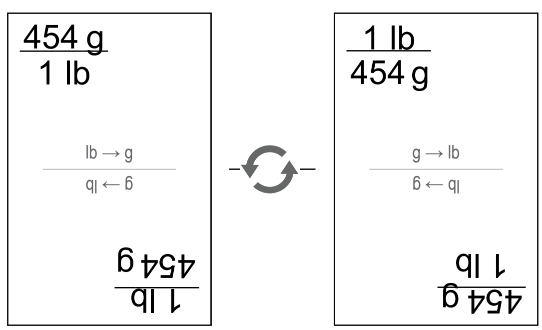
Example 1: One Step Conversion

How many pounds are in 60 grams? (454 grams = 1 pound)



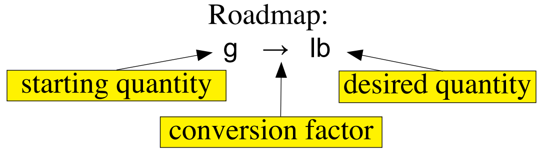
The abbreviation for grams is “g” and the abbreviation pounds is “lb”. The conversion factor 454 g = 1 lb can be written two ways depending on its application. The Type 1 Conversion card corresponding to this conversion factor is shown. Notice how rotating the card changes the numerator and denominator.

$$\frac{454\text{ g}}{1\text{ lb}} \text{ or } \frac{1\text{ lb}}{454\text{ g}} \begin{array}{l}\leftarrow \text{numerator}\\ \leftarrow \text{denominator}\end{array}$$



For some, using a roadmap for conversion problems can be helpful. The roadmap uses only units and each arrow represents a conversion factor.

Roadmap:



Putting all of this together, the answer to Example 1 would be:

$$\frac{60\text{ g}}{1}\left|\frac{1\text{ lb}}{454\text{ g}}\right. \qquad \frac{60\text{ }\cancel{\text{g}}}{1}\left|\frac{1\text{ lb}}{454\text{ }\cancel{\text{g}}}\right. = 0.132\text{ lb}^*$$

Notice how the numerator units and the denominator units cancel each other in the second figure. The solution is 60 ÷ 454, which is 0.132 lb.

* Adjustments to the significant figures in 0.132 oz will be made later.

Example 2: Multi-Step Conversion

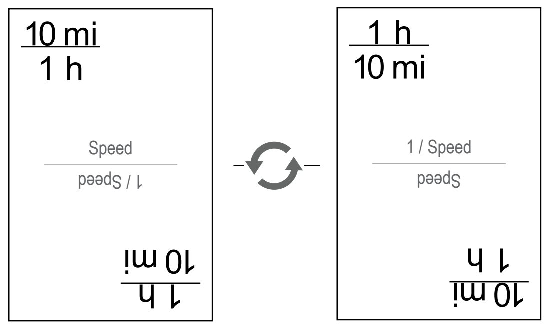
The circumference of the earth is roughly 25,000 mi. How many days would it take someone traveling 10 mph continuously to cover an equivalent distance?

conversion factor | starting quantity | desired quantity

$$\frac{25{,}000\ \text{mi}}{1}\ \Big|\ \quad \Big|\ \quad \Big|\ \quad$$

The conversion factor 10 mph can be rewritten as 10 mi = 1 h. The Type 2 Conversion card corresponding to this conversion factor is shown. Notice how rotating the card changes the numerator and denominator.

$$\frac{10\ \text{mi}}{1\ \text{h}} \quad \text{or} \quad \frac{1\ \text{h}}{10\ \text{mi}} \quad \begin{array}{l} \leftarrow \text{numerator} \\ \leftarrow \text{denominator} \end{array}$$



Roadmap: mi → h → d

Putting all of this together, the solution to Example 2 would be:

$$\frac{25{,}000\ \cancel{\text{mi}}}{1}\ \Big|\ \frac{1\ \cancel{\text{h}}}{10\ \cancel{\text{mi}}}\ \Big|\ \frac{1\ \text{d}}{24\ \cancel{\text{h}}}\ \Big| = 104.166\ \text{d}$$

After completing unit conversion, it is necessary to adjust answers to the correct number of significant figures. The equipment's precision is indicated by the quantity of significant figures expressed in the answers.

Significant Figures (SF)

1. Zeros in the middle of a measurement are significant.

   94.072 g (5 SF) 0.002907 m (4 SF)

2. Zeros at the beginning of a measurement are not significant.

   0.00834 cm (3 SF) 0.002907 m (4 SF)

3. Zeros at the end of the measurement after the decimal point are significant.

   138.20 m (5 SF) 4.80 mL (3 SF)

4. Zeros at the end of a measurement before an implied decimal point are not significant.

   3510 m (3 SF) 23,000 mi (2 SF)

5. All nonzero digits in a measurement are significant.

   7532 s (4 SF) 2.1395 g (5 SF)

The "]" is used to indicate what digits are being kept and what digits are being dropped.

keeping]dropping

7.04]97 g → 7.05 g

Significant Figures in Calculations

Adding and Subtracting

The answer cannot have more digits **after the decimal point** than either of the original measured numbers.

2.23 g	2 after the decimal point
+ 4.8197 g	4 after the decimal point
7.0497 g	7.04]97 → 7.05 g

The measured number 2.23 g has 2 digits after the decimal point and 4.8197 g has 4 digits after the decimal point. The answer must be expressed to 2 digits following the decimal point after rounding.

Multiplying and Dividing

The answer cannot have more significant figures than either of the original measured numbers.

$\frac{42.3\ mi}{2.8\ gal}$ = 15.]107 mpg → 15 mpg

The measured number 42.3 mi has 3 SF, and 2.8 gal has 2 SF. The answer must be expressed to 2 SF after rounding.

After applying the rules of significant figures in calculations, the answers to Examples 1 and 2 are adjusted as follows.

Example 1: $\frac{60\ \cancel{g}}{1} \Big| \frac{1\ oz}{28\ \cancel{g}}$ = 2.]14 oz → 2 oz (adjusted to 1 SF because 60 g has 1 SF)

Example 2: $\frac{25{,}000\ \cancel{mi}}{1} \Big| \frac{1\ \cancel{h}}{3\ \cancel{mi}} \Big| \frac{1\ d}{24\ \cancel{h}}$ = 34]7.22 d → 350 d (adjusted to 2 SF because 25,000 has 2 SF)

Combining Operations

Carry out the operations in parentheses first. Make note of the correct number of significant figures and carry all digits through to the next step. Adjust the final answer to the correct number of significant figures.

$$\frac{(8.6\text{ g} - 8.41\text{ g})}{8.41\text{ g}} \times 100\% = 2\%$$

Step 1:

$$\begin{array}{r} 8.6\ \ \text{g} \\ -\ 8.41\ \text{g} \\ \hline 0.1]9 \\ 0.\underline{1}9\ \text{g} \end{array}$$

The measured number 8.6 g has one digit after the decimal point. After following the subtraction rules for significant figures, the result will be one digit after the decimal point. For an accurate answer, continue using all the digits through to the next step.

Step 2:

$$\frac{0.\underline{1}9\text{ g}}{8.41\text{ g}} \times 100\% = 2.]259 \rightarrow 2\%$$

After division, the lowest number of significant figures is used to determine the final significant figures. Step 1 allows 1 significant figure. The final answer can only have 1 significant figure.

Note: The "100" in 100% is an exact number; therefore, is not considered for significant figures.

> The "_" is used to indicate the final significant figure.
>
> $0.\underline{1}9$ g
>
> (adjust to 1 SF)
>
> This notation can help prevent rounding errors.

Rounding

1. If the first digit to be removed is a 4 or less, drop it and all of the following digits.

Adjust to two SF: 2.4]3̲71 g → 2.4 g
↑

The first digit being dropped is the only digit to examine for rounding. Since 3 is less than 4, it is dropped.

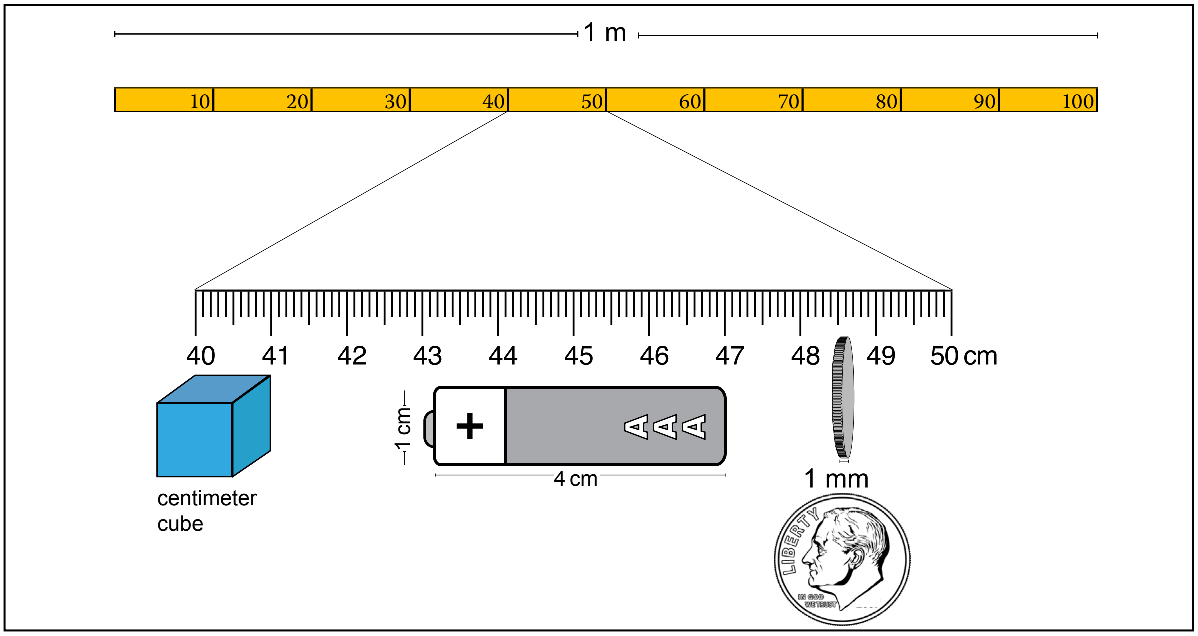
2. If the first digit removed is 5 or greater, round the number up by adding 1 to the last retained digit.

Adjust to two SF: 4.5]8̲32 m → 4.6 m
↑

The first digit being dropped is 8, so the number to the left is increased by 1.

Prefix Multipliers

Centi- and *milli-* are prefix multipliers, so these prefixes can be applied to units other than meters. Prefix multipliers are often used in unit conversion. It can be hard to understand the relationship between prefix multipliers and base units without context. A meter stick can help. A one-meter stick has 100 markings showing centimeters. As a tip for remembering *centi-*, there are 100 cents in one U.S. or Canadian dollar.



One meter has 100 centimeters. A centimeter cube and the diameter of a AAA battery have a width of 1 cm. The edge of a U.S. dime is approximately 1 mm.

The conversion factors that result from these relationships are shown below. They are Type 1 conversion cards found in the Conversion deck.

Equivalent	Conversion Factors
1 m = 100 cm	$\frac{1\ \text{m}}{100\ \text{cm}}$ or $\frac{100\ \text{cm}}{1\ \text{m}}$
1 m = 1000 mm	$\frac{1\ \text{m}}{1000\ \text{mm}}$ or $\frac{1000\ \text{mm}}{1\ \text{m}}$
1 cm = 10 mm	$\frac{10\ \text{mm}}{1\ \text{cm}}$ or $\frac{1\ \text{cm}}{10\ \text{mm}}$

The same process can be carried out for the prefix *kilo-*. A kilometer is one thousand times longer than a meter. Two equivalents can be generated between kilometer and meter: 1 km = 1000 m or 10^{-3} km = 0.001 km = 1 m. It is often easier to mentally visualize 1 km = 1000 m. From this equivalent two conversion factors can be generated.

Equivalent	Conversion Factors
1 km = 1000 m	$\frac{1\ \text{km}}{1000\ \text{m}}$ or $\frac{1000\ \text{m}}{1\ \text{km}}$

The first few games are aimed at significant figures and later ones focus on converting between various metric prefixes (for example: *kilo-*, *centi-*, and *milli-*). As the games progress, more emphasis is placed on unit cancellation and later games use more Conversion cards and Prompt cards.

UC1 Significant Figure (SF) Pile Up

Objective: To practice identifying how many significant figures are in measured numbers.

Number of players: Two to four.

Cards: Complete Volume or Mass card decks.

Deal: Shuffle the cards. Deal the whole deck among all players. It does not matter if one of the players receives an extra card. Players do not look at their cards, but leave them face down on the table in a stack.

Object of the game: To get rid of all cards by sorting them into the correct significant figure piles.

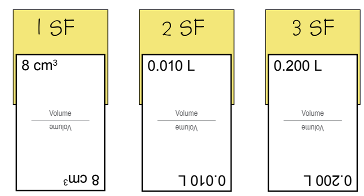
Play: Place three small sheets of paper in the center of the playing area with the following labels: "1 SF," "2 SF," and "3 SF."

The player to the left of the dealer turns over their top card and places the card under the correct significant figure label. If the player places their card in an incorrect pile, the player retrieves their card and places it at the bottom of their stack. Play can move quickly, so be sure everyone is paying attention.

If the card is placed correctly, the game continues around the table until one player places all their cards. The player who runs out of cards first wins the game.

Variation 1: Use all the Volume, Mass, and Length card decks at the same time.

Variation 2: Play as a solitaire and time how quickly all the cards can be sorted.



The three different measurements are paired with the correct significant figure amounts.

UC2 Significant Figure War: Volume or Mass

Objective: To practice identifying how many significant figures are in measured numbers.

Number of players: Two.

Cards: A deck of either the Volume or Mass cards.

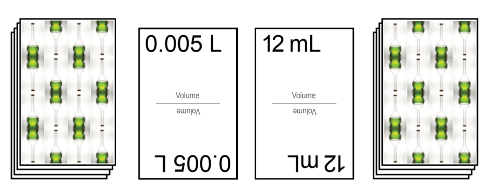
Deal: Each player receives half of the shuffled deck face down in front of them.

Object of the game: To capture most of the cards by comparing the number of significant figures.

Play: Players turn over the top card and lay it face up on the table. Both players say the quantity of significant figures aloud on their card. Note that no conversion is necessary. The player who has the card bearing the most significant figures wins both cards. Make sure that both players agree with the results. The two cards are placed in a separate winnings pile, one for each player.

If the cards turned over have the same number of significant figures, a war is declared. Each player places one card face down and one card face up. The player with the greater number of significant figures on their new face up card takes all six cards.

The game continues until the original stack of cards is exhausted or the allotted time for the game has ended. Players compare the height of their winnings pile to determine the winner.



The card on the right wins because 12 mL has two significant figures and 0.005 L has one significant figure.

Variation: Use all the Volume, Mass, and Length card decks shuffled together.

UC3 Round to One Significant Figure

Objective: To practice rounding measured numbers to one significant figure.

Number of players: Two.

Cards: Mass cards:

One of each: 2 g, 20 g, 3 g, 30 g, 2000 mg, 20,000 mg, 15,000 mg, 16,000 mg, 24,000 mg

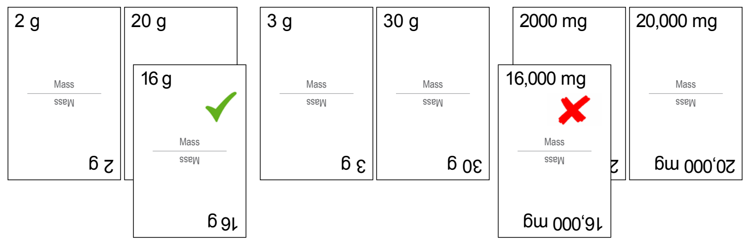
Two of each: 15 g, 16 g, 24 g, 28 g

Deal: Lay out the following cards face up between two players: 2 g, 20 g, 3 g, 30 g, 2000 mg, 20,000 mg as shown below. Shuffle the rest of the cards and place face down.

Object of the game: To collect the most pairs of correctly matched measurements.

Play: Players alternate turning over a card and matching it to the correctly rounded measurement. If a player matches incorrectly, the incorrect card is turned over and placed on top of the incorrect answer. Any match to 2 g, 3 g, or 2000 mg is incorrect, because there are no matching cards.

When two of the same cards are placed on the rounded measurement, the player placing the second card picks up the other matching card and places the pair of cards in their winnings pile.



The 16 g card is correctly rounded to 20 g and placed face up.

The 16,000 mg card is placed incorrectly on the 2000 mg card. Because it is rounded incorrectly, it will be placed face down and not be considered a matched pair.

The game continues until cards are exhausted. The player having the most pairs wins.

UC4 After the Decimal Point: Addition War

Objective: To apply the significant figure rules for addition.

Background: Solving calculations involving significant figures correctly requires practice. The rule for calculations involving addition and subtraction is:

> The answer cannot have more digits to the right of the decimal point than either of the original measured numbers.

Digits are defined as any number between 0 to 9. The following calculation 0.030 L + 0.010 L results in an sum with three digits after the decimal point, 0.040 L because both of the addends have three digits after the decimal point.

Number of players: Two, sitting on the same side of the table.

Manipulatives: Paper, pencil, and calculator.

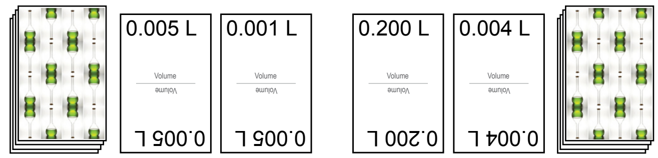
Cards: A deck of Volume cards containing only units of liters, 20 cards total.

Deal: Each player receives half of the shuffled deck face down in front of them.

Object of the game: To capture most of the cards by comparing the sum of two Volume measurements to the correct number of significant figures

Play: Players each turn over their two top cards and lay them face up next to each other and add their volumes. Then, each player states their answer to the correct number of significant figures, which will always be three digits after the decimal point. The player who has the larger sum wins all four cards. The players keep track of cards won in a separate winnings pile.

If the cards turned over have the same sum, a war is declared. Each player turns over two cards and lays them face up next two each other. The player with the larger difference on their new face up cards takes all eight cards.



Left: 0.005 L + 0.001 L = 0.006 L

Right: 0.200 L + 0.004 L = 0.204 L

The player on the right wins the war.

The game continues until the original stack of cards is exhausted or the allotted time for the game has ended. Players compare the height of their winnings pile to determine the winner.

Variation: Play the game as above, but using subtraction.

UC5 After the Decimal Point War

Objective: To apply the significant figure rules for addition and subtraction.

Background: Solving calculations involving significant figures correctly requires practice. The rule for calculations involving addition and subtraction is:

> The answer cannot have more digits to the right of the decimal point than either of the original measured numbers.

Digits are defined as any number between 0 to 9. The following calculation 0.036 kg – 0.016 kg results in an difference with three digits after the decimal point, 0.020 kg.

Number of players: Two, sitting on the same side of the table.

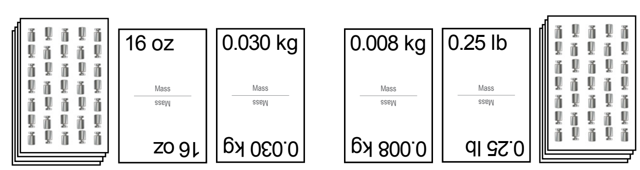
Manipulatives: Paper, pencil, and calculator.

Cards: A deck of Mass cards containing only units of kilograms (kg), pounds (lb), and ounces (oz); 24 cards total.

Deal: Each player receives half of the shuffled deck face down in front of them.

Object of the game: To capture most of the cards by having the most allowed after the decimal point with either addition or subtraction. It is not necessary to calculate the answer resulting from addition or subtraction, rather determining how many digits are allowed after the decimal point. Units are ignored completely.

Play: Players each turn over their two top cards and lay them face up next to each other. Players determine how many digits are allowed after the decimal point with both of their measurements. For example, with the cards 0.008 kg and 0.25 lb, two digits after the decimal point is the most allowed. It is not necessary to calculate the answer or have the same unit. Each player states their allowed minimum number of digits after the decimal point. The player who has the most digits allowed (either 0, 2, or 3) after the decimal point wins all four cards. The four cards are placed in a separate winnings pile.



Left: Zero after the decimal point allowed.

Right: Two after the decimal point allowed.

The player on the right wins.

If the cards turned over have the same number of digits after the decimal point allowed, a war is declared. Each player turns over two cards and lays them face up next two each other. The player with the larger number of allowed digits after the decimal point takes all eight cards.

The game continues until the original stack of cards is exhausted or the allotted time for the game has ended. Players compare the height of their winnings pile to determine the winner.

DENSITY (D)

Imagine there are two identical cardboard boxes filled with different substances. One box is filled with loosely filled with feathers and the other box is filled with bricks. The boxes have the same volume. You help carry a box; it does not matter which box you choose. Which box would you choose? Why?

Most would answer they would choose the box containing feathers since it is lighter. Others might choose the box containing bricks to get more exercise. Regardless of which box you would choose, the difference in these boxes has to do with density. Density is a measure that compares the "heaviness" of two objects having the same volume.

Density is a concept that is covered early in most introductory chemistry courses. It is defined as mass divided by volume, as shown in the equation below.

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \quad \text{or} \quad d = m/v$$

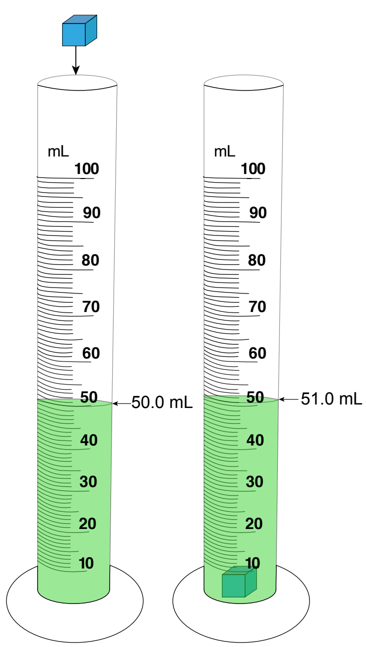
Often units of density are given as grams per milliliter (g/mL) for liquids and grams per cubic centimeter (g/cm^3) for solids. Density varies for different substances and is expressed in fundamental units.

Confusion can arise when students try to make sense of density units. For printing reasons, density is often written using a slash to indicate "per." Density should always be treated as two units which is consistent with more advanced chemistry calculations.

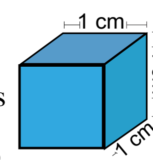
Density of Copper is 8.96 g/cm^3 or $\frac{8.96\text{ g}}{1\text{ cm}^3}$ ← numerator ← denominator

It is necessary to distinguish the numerator from the denominator to cancel units.

It is also important to realize and understand that the volume of 1 mL is equal to 1 cm^3. This means that **densities given in units of g/mL or g/cm^3 are the same.** One way to demonstrate this is with water displacement using a centimeter cube, which is 1 cm × 1 cm × 1 cm, and weighs one gram.



Dropping a centimeter cube into a graduated cylinder of water results in the volume increasing 1.0 mL.



A 100 mL graduated cylinder (used to measure volume in mL) is filled with 50.0 mL of water. The centimeter cube is dropped into the graduated cylinder. The new volume is 51.0 mL. The volume by water displacement of the cube can be calculated by subtracting 51.0 mL – 50.0 mL = 1.0 mL. The volume of the cube uses the formula

$$V = l \times w \times h = 1\text{ cm} \times 1\text{ cm} \times 1\text{ cm} = 1\text{ cm}^3$$

This exercise shows 1 mL is equal to 1 cm^3.

Another source of confusion for students is different abbreviations for units. In the medical profession, cubic centimeters (cm^3) are sometimes abbreviated as *cc* standing for cubic centimeters. Medications are administered in cc as well as mL.

Objects with densities greater than 1.00 g/mL will sink in water. Copper has a density of 8.96 g/cm^3 and sinks in water. Objects with densities less than 1.00 g/mL will float in water. Ice has a density of 0.92 g/cm^3 and floats in water.

The games in this section initially focus on getting comfortable with manipulating the density equation using unit cancellation.

D1 Making One

Objective: To introduce players to unit cancellation using equivalent densities.

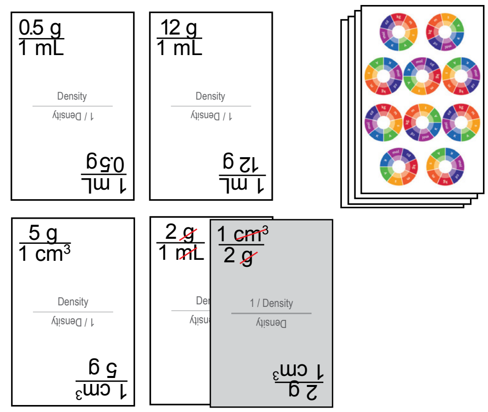
Number of players: Two.

Cards: A deck of 26 Conversion cards with units of g/mL and g/cm^3.

Deal: Shuffle the cards. Deal four cards to each player. Place four cards face up in the center of the table and place the remaining cards face down to form a draw pile.

Object of the game: To collect the most pairs by finding a pair that makes 1.

Play: Players cancel units of grams by placing the equivalent density next to an inverted density. The first player takes their turn by matching pairs within their hand, among the cards on the table, or a card in their hand to a card on the table. After a player concludes their turn, the player replenishes the cards to have four in their hand and four on the table. Even if they pick up a match, the player cannot play until their next turn.



When 2 g/mL is paired with its inverse density of 1/2 cm^3/g, the results make 1.

The pair that makes 1 is set aside in the player's winnings pile. If a player cannot play a card, they draw a card from the draw pile, but this ends their turn.

When the stock pile of cards is depleted and a play is not possible, the player takes one card from their hand and places it face up on the table. The game continues until all cards are matched. The player having the most cards is the winner.

D2 Density Pairs: g/mL and g/cm^3

This is a variation of the traditional Old Maid game.

Objective: To introduce players to different units of density (g/mL = g/cm^3).

Number of players: Two.

Cards: Conversion cards with units of g/mL and g/cm^3. For each player, choose five or six pairs of equivalent densities (example: 2 g/mL and 2 g/cm^3 or 12 g/mL and 12 g/cm^3).

Deal: Shuffle the cards. Remove one card without looking at it and set it aside face down. Deal the remaining cards to both players. One player will receive an extra card.

Object of the game: To avoid having the last unpaired card.

Play: Players match equivalent densities found in their hands and set them aside.

When all players are ready, player A holds their cards fanned out face down while player B takes a card. Player B checks for a match and sets the matched pair aside if one is present. Next, player A chooses a card from player B's fanned out face down cards.

The game continues until one player is left with the unpaired card. The players should check that this unpaired card matches the card originally set aside.

D3 Density War: Mass Divided by Volume

Objective: To practice estimating density quotients and to recognize that one milliliter (1 mL) is equivalent to one cubic centimeter (1 cm^3).

Number of players: Two, sitting on the same side of a table.

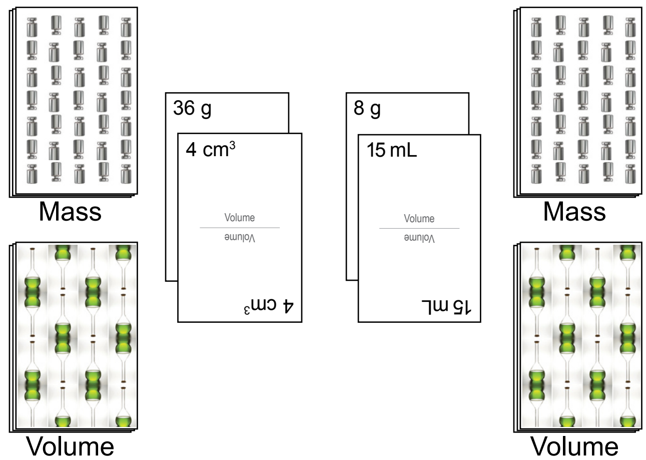
Cards: A deck of 29 Mass cards with units of g and a deck of 37 Volume cards with units of mL or cm^3.

Deal: Before dealing, remove one Mass card and nine Volume cards and set them aside. Each player receives half of each deck, one deck of mass and one deck of volume, in two piles face down.

Object of the game: To capture most of the cards. The mass is the numerator and the volume is the denominator. The player with the higher density wins both cards.

Play: Both players turn over the top card of each pile. Players perform the division mentally, which might involve estimation and rounding, and state the density including the correct units. The player with the higher density collects all four cards.

If the densities are equal, a war is declared and each player puts face down one of each card. Then the players form another density face up and state the answers with units. The player with the higher density of the new cards captures all the cards. The game continues until the original stack of cards is exhausted or the allotted time for the game has ended. Players compare the height of their winnings piles to determine the winner.



Left: 36 g/4 cm^3 = 9 g/cm^3
Right: 8 g/15 mL ≅ 0.5 g/mL
The player on the left wins this war.

If extra estimation practice is needed, players should refer to UC26 Speed War: mi/min or mi/h on page 31.

Variation: Play Peace; the player with the lower density wins both cards.

D4 Mass War: Volume Multiplied by Density

Objective: To practice unit cancellation and recognize that 1 mL is equivalent to 1 cm^3, a cubic centimeter.

Background: When density and volume are known, the density equation can be rearranged to solve for mass.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$ divide both sides by density and multiply both sides by volume

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}}$$

Using unit conversion can demonstrate the algebraic manipulation above with mass as a starting quantity and density as a conversion factor.

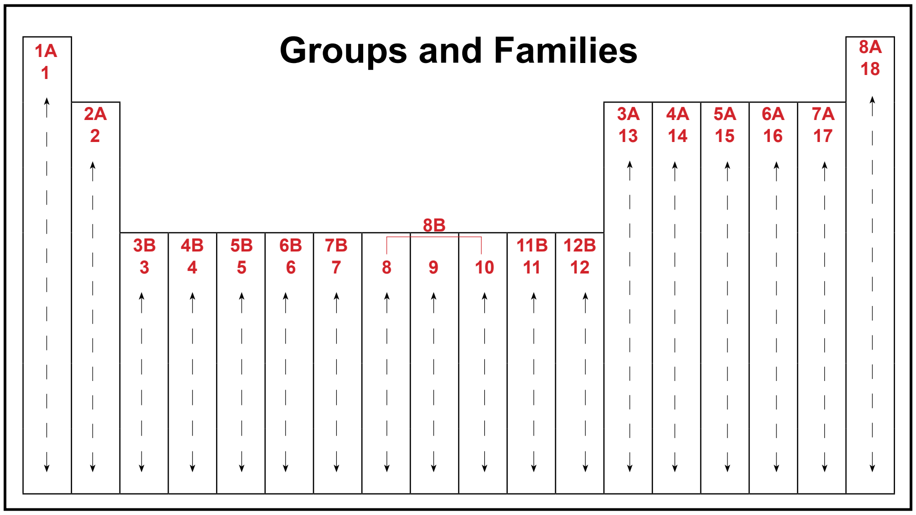
$$\frac{\cancel{g}}{1} \Big| \frac{mL}{\cancel{g}} = mL$$

Use of a Type 2 conversion factor occurs from a given situation, such as, I am bicycling 10 miles per hour (10 mi/h) or density, such as water has a density of 1 g/mL or copper has a density of 9 g/cm^3.

Number of players: Two, sitting on the same side of the table.

PERIODIC TABLE (PT)

The periodic table contains vast amounts of useful information making it a challenge to learn and use all of its attributes. The games in this section are intended to familiarize players with some of the many features of this comprehensive table. These features include groups and families, valence electrons, and atomic weights.

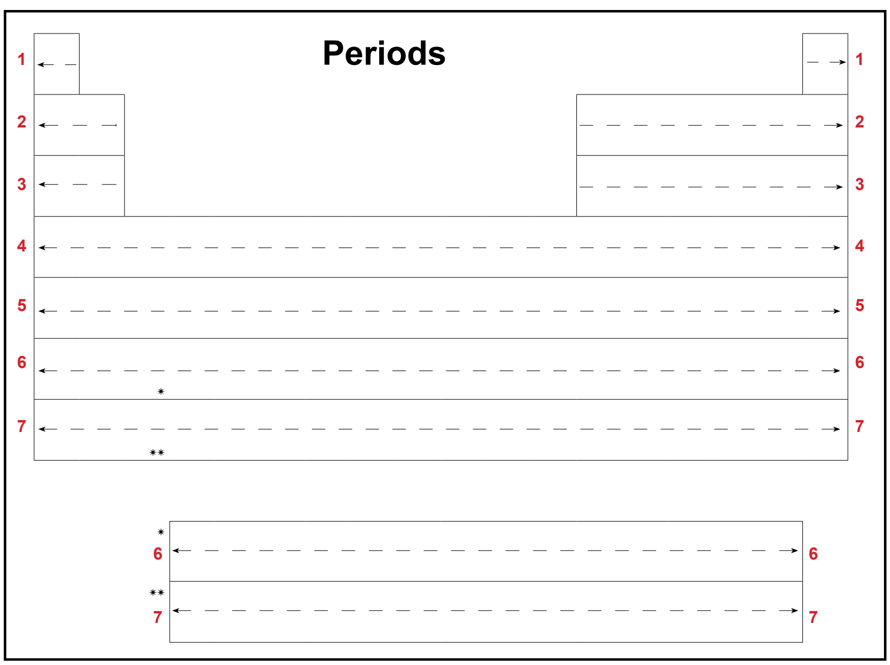


The labels above each column of the periodic table identify the vertical column, or group. There are two types of identifiers, 1A to 8A (and a few with the B identifier: 3B, 4B, 5B etc.) used by the Chemical Abstracts Service and the numbering 1 to 18 is adopted by the International Union of Pure and Applied Chemistry (IUPAC). Groups with the A designation or groups 1, 2, and 13 to 18 are main group elements.

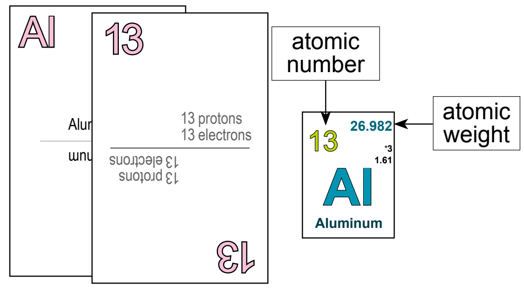
IUPAC has not established a consistent group numbering system for the lanthanides and actinides (the island at the bottom of the periodic table consisting of atomic numbers 57 to 71 and 89 to 103). Often, main group elements will have a family name, as shown in the table to the right.

Group Number	Family Name
1A/1	Alkali Metals
2A/2	Alkaline Earth Metals
7A/17	Halogens
8A/18	Noble Gases

Dmitri Mendeleev determined the basic table arrangement in 1869. Each group or vertical column shares similar properties. This repeats again in each row leading to the periodicity observed throughout the table. The periodicity also allowed Mendeleev to correctly predict the properties of elements not yet discovered. Periods are the horizontal rows numbered 1 to 7.



The atomic number is listed in green in the periodic table (found on the inside front cover of this manual and on the Trifold). The atomic number tells how many protons are in a given element. The number of protons is used to identify elements. In a neutral atom, the number of electrons is the same as the number of protons. For example, aluminum will always have 13 protons, while the number of electrons can vary.



Aluminum's Element and Atomic Number cards next to periodic table. Neutral aluminum has 13 protons and 13 electrons.

The electron arrangement predicts an element's behavior. Electrons are "parked" in energy levels around the nucleus of an atom. Each energy level has a certain maximum number of electrons shown below. The first three energy levels are shown, although there are more.

Maximum Electrons in each Energy Level	
Energy Level	Max electrons
1	2
2	8
3	8

The outermost shell in which electrons reside impacts element properties and chemical behavior. The outermost shell of electrons is called the valence electrons. Other than hydrogen and helium, most atoms strive to have eight valence electrons, called an octet. Atoms that do not have 8 electrons will gain, share, or lose electrons in order to achieve an octet.

For example, sodium, which is atomic number 11 and in group 1A/1, has 1 valence electron (two electrons in energy level one and eight electrons in energy level two, one electron in energy level three). Sodium tends to lose this valence electron, resulting in an octet in its second energy level like that seen in neon. Neon is a noble gas, which is stable due to its octet, the eight valence electrons.

Chlorine, on the other hand, has 7 valence electrons because it is in group 7A/17 (2 electrons in energy level one, eight electrons in energy level two, and 7 electrons in energy level three). Chlorine tends to gain an electron to achieve an octet. This results in an outer shell like that seen in argon. Note that neon and argon are inert; they do not react. This is because their outer shells contain an octet. Sodium and chlorine each contain an octet when chlorine gains an electron from sodium.

The periodic table shows the number of valence electrons present in neutral atoms based on the group number.

Note that while 1A, 2A, 7A, and 8A are very predictable, other groups display more variation in how many electrons they will gain or lose.

Group Number	Valence electrons
1A/1	1
2A/2	2
3B/3	varies with transition metal
4B/4	varies with transition metal
5B/5	varies with transition metal
6B/6	varies with transition metal
7B/7	varies with transition metal
8B/8	varies with transition metal
8B/9	varies with transition metal
8B/10	varies with transition metal
1B/11	varies with transition metal
2B/12	varies with transition metal
3A/13	3 and varies with other metals
4A/14	4 for nonmetals and metalloids, others vary
5A/15	5 for nonmetals and metalloids, others vary
6A/16	6 for nonmetals and metalloids, others vary
7A/17	7
8A/18	8

PT1 Find the Elements

Objective: To familiarize players with element abbreviations and their locations on the periodic table.

Background: In this game, players locate the element on the periodic table using the element name and abbreviation on the element card.

Manipulatives: Periodic table and centimeter cubes for each player.

Number of players: Two or three.

Cards: A random half of the deck of Element cards and the Color Key card for reference.

Deal: Element cards are placed face down in a stack.

Object of the game: To place the most centimeter cubes on your periodic table.

Play: Players alternate turning over an Element card. The player turning over the card must state both the name and abbreviation of the element card while making it visible to all players.

When the name and abbreviation of the element is stated, players look at their periodic tables for the element. The first player to find the element calls out, "FOUND IT!" and states the atomic number and places a centimeter cube over that element on their periodic table. A player may claim the same element twice.

Game continues until the cards are exhausted. The player having the most cubes on their periodic table is the winner.

Variation 1: Choose a caller who states the element cards stating both the name and abbreviation.

Variation 2: Play several times as a solitaire and time how quickly the elements can be found.

PT2 Element War

Objective: To familiarize students with the periodic table and the concept of atomic number.

Background: In this game, players find the element abbreviation on the periodic table from the card they turn over during this Element War game. The cards contain the name and abbreviation of each element. If the abbreviation is based on the element's Latin name, it is also given. For example, gold has a symbol of Au. The symbol Au is referring to the Latin name for gold, which is *aurum*.

The atomic number will be the main focus for this game; for example, the atomic number for gold, Au, is 79. It is important to note that the atomic number also indicates how many protons and electrons are present in a neutral atom. This will be explored further in other games.

Manipulatives: Multi-colored Periodic table on the Chemistry Trifold. Note: the same Periodic table is on the reverse side of the Element cards.

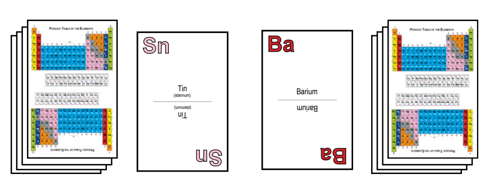
Number of players: Two.

Cards: The complete deck of Element cards.

Deal: Divide the cards into two equal stacks by comparing height. Place stack face down in front of each player.

Object of the game: To capture all the cards. Win the most cards by comparing the element's atomic numbers and group locations on the periodic table. The higher atomic number wins both cards.

Play: Players turn over the top card and lay it face up. Players may refer to the periodic table to look up the atomic number of the element listed on the their card as well as the group location on the color coded Periodic table. If the elements are in different groups (different card colors), the player who has the card bearing the element with the higher atomic number collects both cards.



Left: Sn has an atomic number of 50.
Right: Ba has an atomic number of 56.
The player on the right wins this war.

In the event that players turn over the same Element cards OR Element cards in the same group (same color cards), a war is called. To resolve this, both players play one card face down and then play a third card face up to be compared. If the elements are in different groups, the player who has the card bearing the element with the higher atomic number of the last two cards played takes all six cards.

Once both players have gone through their first stack, they both turn over their winnings pile and the game continues until one player runs out of cards.

Variation: Play Peace; the player who has the lower atomic number wins both cards.

PT3 Rows, Columns, and Diagonals Solitaire: Periodic Table

Objective: To familiarize players with the concept of atomic number and locations of elements on the periodic table.

Background: In this game, players use the periodic table to look up the atomic number and determine the element's identity based on the atomic number.

Manipulatives: Periodic table or Chemistry Trifold.

Cards: The decks of Element cards and Atomic Number cards.

Deal: The Atomic Number cards are shuffled and placed in a stack face down near all players.

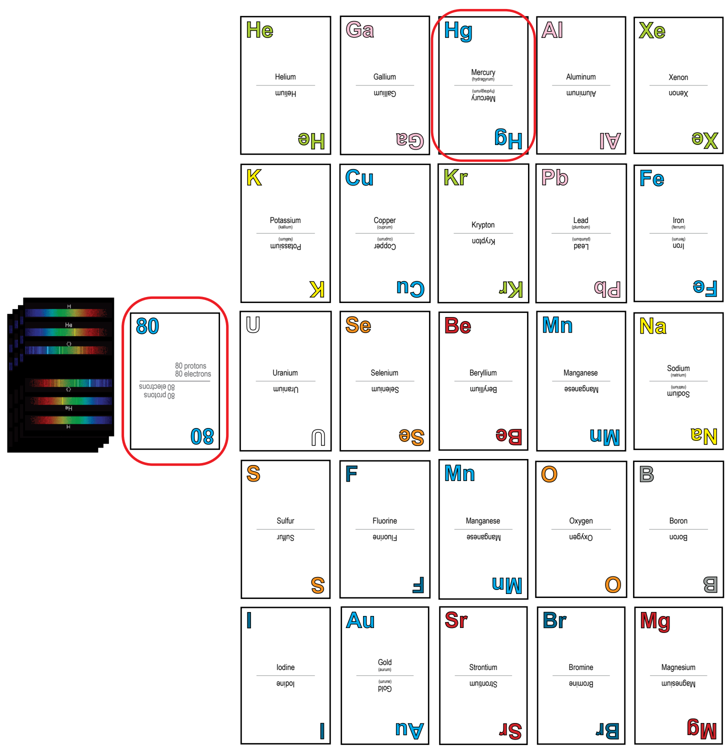
Layout: Each player lays out 25 Element cards face up in a random 5 × 5 grid.

Object of the game: To be the first player to turn over either a row, column, diagonal, or the four corners with cards. There may be ties.

Play: A player turns over the Atomic Number card and clearly says it aloud. Each player looks at their periodic table to determine what element matches the atomic number. The players then look at their grid. If the Atomic Number called matches any element on their grid, then that Element card is turned over.

If a player has two cards of the same element, both cards are turned over when that Atomic Number is called.

Players alternate turning over the Atomic Number card. After a player wins by turning over a row, column, or diagonal, verify the Element cards.



The Element card Hg would be turned over in this example.

Variation 1: Take a short break after each atomic number is called to read about the element that has that atomic number. A great resource for this is Theodore Gray's book, *Elements: A Visual Exploration of Every Known Atom in the Universe*. The elements are arranged by ascending atomic number in this beautiful and informative book.

Variation 2: Play a round where general groupings are called out after the Atomic number is drawn: transition metal, alkali metal, alkaline earth metal, other metal, metalloid, non-metal, noble gas, or inner transition metal, found on the key on the color coded Periodic table on the Chemistry Trifold and the reverse side of the Element cards. All cards within that grouping are turned over.

IONIC COMPOUNDS (IC)

Ionic compounds are made up of charged species called ions. Ions are formed when neutral atoms lose or gain electrons. Electrons reside outside of the nucleus, have a negligible mass, and have a charge of negative one. Typically, metals lose electrons to form positively charged ions, called *cations*, and nonmetals gain electrons to form negatively charged ions, called *anions*.

Ionic compounds are composed of a cation and an anion. Ionic compounds are always written so that the overall charge adds up to zero. The format of ionic compounds is written with the cation (positively charged ion) first and the anion (negatively charged ion) second.

Sodium ion (Na^+) and chloride ion (Cl^-) form sodium chloride, known as common table salt.

$$Na^+ \quad Cl^-$$
$$1^+ + 1^- = 0$$
$$NaCl$$
2 ions total

Sodium ion (Na^+) and phosphate ion (PO_4^{3-}) form sodium phosphate (used as thickening agents and leavening agents for baked goods).

$$Na^+ \quad PO_4^{3-}$$
$$(1^+ \times 3) + 3^- = 0$$
$$Na_3PO_4$$
4 ions total

Note that PO_4^{3-} is treated as a single unit, despite being made up of more than one atom. It is an example of a polyatomic ion. The *poly-* prefix means more than one. If only one polyatomic ion is present, parentheses are not needed. When more than one polyatomic ion is present, such as carbonate, CO_3^{2-}, it is placed in parentheses as shown below:

$$Fe^{3+} \quad CO_3^{2-}$$
$$(3^+ \times 2) + (2^- \times 3) = 0$$
$$Fe_2(CO_3)_3$$
5 ions total

The correct formula for iron (III) carbonate is $Fe_2(CO_3)_3$. The "III" refers to the 3^+ charge on iron, not the number of iron atoms. On the other hand, iron (II) carbonate is $FeCO_3$. Iron is a transition metal, which can form more than one cation; this is why it is necessary to specify the ion in the name with a Roman numeral. Recall that the correct formula for ionic compounds is the simplest ratio of ions.

	Ca^{2+} S^{2-}	Sn^{4+} O^{2-}
Unsimplified incorrect formulas	Ca_2S_2	Sn_2O_4
Correct formulas	**CaS**	$\mathbf{SnO_2}$

Because atoms are very small, instead of using a unit, like a dozen, to keep track of how many atoms, ions, or molecules are necessary, the unit *mole* is used. A mole is defined as 6.022×10^{23} "things". If you are dealing in pure elements, then the things would be atoms. If ionic compounds are being counted, then a mole of an ionic compounds would be referring to ions.

Since atoms are so small and difficult to count, the mass of 1 mole of atoms is referred to as the molar mass. This information can be found on the periodic table underneath the elements and is expressed in atomic mass units (amu), or atomic weight, relative to carbon-12. Sodium has an atomic weight of 22.99 amu. The molar mass of sodium is 22.99 g/mol. One mole of sodium atoms has a mass of 22.99 g. So if you had 22.99 g of sodium, it would contain 6.022×10^{23} atoms of sodium.

For compounds, two or more elements combined in fixed proportions, the molar mass is calculated using the subscripts in the chemical formula. The molar mass of sodium chloride, NaCl (salt), would be calculated as follows:

NaCl			
Na		(1 × 22.99)	g/mol
Cl	+	(1 × 35.45)	g/mol
		58.44	g/mol

Most element's atomic weights have three places after the decimal. For simplicity, molar mass calculations will be expressed to two decimal points.

Notice that NaCl does not have subscripts explicitly written. When this is the case, the number of atoms is one.

The formula for sodium phosphate, Na_3PO_4, has subscripts. The calculation for sodium phosphate's molar mass is shown below:

Na_3PO_4			
Na		(3 × 22.99)	g/mol
P		(1 × 30.97)	g/mol
O	+	(4 × 16.00)	g/mol
		163.94	g/mol

For formulas with parentheses, the subscripts outside the parenthesis are distributed to the atoms within the parenthesis. Iron (III) carbonate, $Fe_2(CO_3)_3$ is an example of one of these compounds. The calculation of its molar mass is shown below:

$Fe_2(CO_3)_3$			
Fe		(2 × 55.85)	g/mol
C		(3 × 12.01)	g/mol
O	+	(9 × 16.00)	g/mol
		291.73	g/mol

IC1 Neutral Element to Atomic Number Memory

Objective: To remind players that neutral elements have equal numbers of protons and electrons, which is the atomic number.

Background: The atomic number is listed in green in the periodic table found on the inside cover of this manual or in the upper left corner of each element on the multi-colored periodic table on the Chemistry Trifold. Each element has a unique atomic number which identifies the element.

In a neutral atom, the number of electrons is the same as the number of protons. This game focuses on just a few elements. To review the periodic table, play PT3 Rows, Columns, and Diagonals Solitaire: Periodic Table on page 65.

Manipulatives: Periodic table.

Number of players: Two.

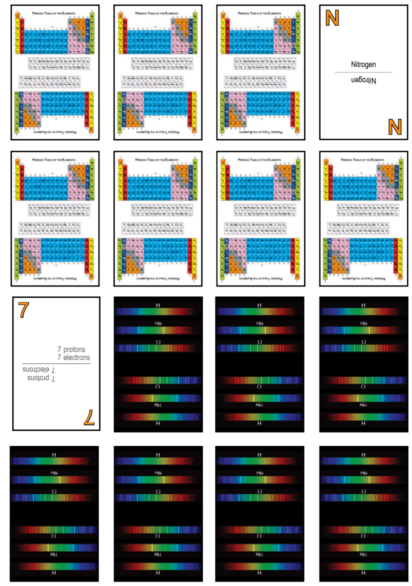
Cards: Eight Atomic Number cards: 11 to 18.

Eight Element cards: Na, Mg, Al, Si, P, S, Cl, Ar.

Deal: Lay out each deck of cards in a 4 × 2 grid, for an overall 4 × 4 array.

Object of the game: To collect the most pairs.

Play: Refer to the periodic table for element names and atomic numbers as needed. The first player turns over one Atomic Number card for both players to see and says the number of protons and electrons (printed on the Atomic Number card) along with element name aloud. This player then attempts to find the matching Element card by turning over a face down Element card.



Nitrogen matches with atomic number 7. The player states, "Neutral nitrogen contains 7 protons and 7 electrons."

If the two cards match, the first player collects them both and continues taking turns until they no longer turn over matching cards.

If the two cards do not match, the first player returns both cards face down in the original place and the other player takes their turn.

Players continue to take turns until all the cards are collected.

IC2 Making Ions from Main Group Elements

Objective: To introduce the concept that ions are formed by either electron loss or gain in order to achieve an octet.

Background: Main group elements are groups 1A to 2A and 3A to 8A (1 to 2 and 3 to 18). Groups 1A to 3A lose valence electrons to form cations (positively charged ions), while groups 5A to 7A gain valence electrons to form anions (negatively charged ions). Either cation or anion formation occurs in order to achieve an electron octet, eight valence electrons, like those found in noble gases.

Manipulatives: Chemistry Trifold, Periodic table, and Ion Table Tents on Appendix pages 8 and 9.

Number of players: Two.

Cards: Element cards listed by name and color:

Alkali metals (yellow, two of each): Li, Na, K

Alkaline earth metals (red, two of each): Be, Mg, Ca, Sr, Ba

Other metals (pink, two of each): Al

Nonmetals: Group 5A (orange, two of each): N, P

Nonmetals: Group 6A (orange, two of each): O, S

Halogens (dark blue, two of each): F, Cl, Br, I

Noble gases (lime green, two of each): He, Ne, Ar, Kr, Xe

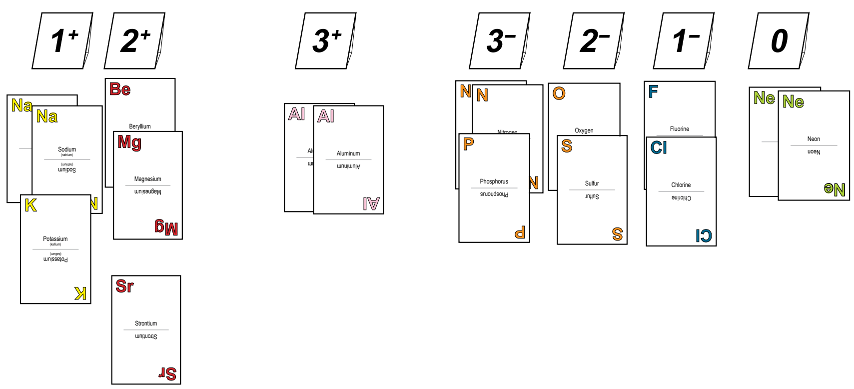
Deal: Shuffle cards and deal all the cards evenly among the two players. Each player will have 22 cards.

Object of the game: To collect the most noble gases.

Play: Players cut, fold, and place the labels in front of them: 1^+, 2^+, 3^+, 3^-, 2^-, 1^-, and 0

Each player sorts their cards by looking at their elements and predicting which elements would gain electrons and which would lose electrons to have an electron arrangement of a noble gas. The periodic table is a great resource for this.

For main group elements, it is best to look at the group number for the charge. For groups 1A, 2A, and 3A, the charge is the group number without the A, such as 1^+, 2^+, and 3^+. For groups 5A, 6A, and 7A, the charge is the group number without the A subtracted from 8. For example, group 5A will have a charge of 3^-. This represents the gain of three electrons to create an octet. Group 8A, noble gases, does not gain or lose electrons, so the charge is 0.



Main group elements are sorted by their ions. As players place the element in the correct charges, they state whether electrons are gained or lost in order to form that ion.

For example, when placing aluminum, Al, a player would say, "Aluminum loses three electrons to form a 3^+ ion and has 10 electrons total." (The atomic number for Al is 13 and three electrons (e^-) are lost for a total of 10 electrons.)

For example, when placing sulfur, S, a player would say, "Sulfur gains two electrons to form a 2^- ion and has 18 electrons total." (The atomic number for S is 16 and two more electrons (e^-) are gained for a total of 18 electrons.)

This player has only one noble gas; therefore, the other player with nine noble gases is the winner.

Electron loss and electron gain and the resulting charge can be a tricky concept to master. Thinking of electrons as "weeds" can be helpful. Usually weeds are unwelcome visitors to lawns or gardens. The gain of weeds is a negative outcome and the loss of weeds is a positive outcome. And, the gain of electrons is a negative ($^-$) outcome and the loss of electrons is a positive ($^+$) outcome.

As players sort their elements, they state whether electron gain or loss is necessary to create an octet and how many total electrons are present.

Within each ion charge, organize the elements according to their colors and arrangement on the periodic table.

After both players have sorted, organized, and checked their cards, the player who has the most noble gases wins the game. In case of a tie, both players are winners.

IC3 Ion War Part One

Objective: To learn how to use the periodic table to predict charges of ions.

Background: The absolute value of a number ignores the sign. For example, $^-2$ and $^+2$ have the same absolute value, 2.

Manipulatives: Periodic table.

Number of players: Two.

Cards: Element cards listed by name and color (same cards as IC2):

Alkali metals (yellow, two of each): Li, Na, K

Alkaline earth metals (red, two of each): Be, Mg, Ca, Sr, Ba

Other metals (pink, two of each): Al

Nonmetals: Group 5A (orange, two of each): N, P

Nonmetals: Group 6A (orange, two of each): O, S

Halogens (dark blue, two of each): F, Cl, Br, I

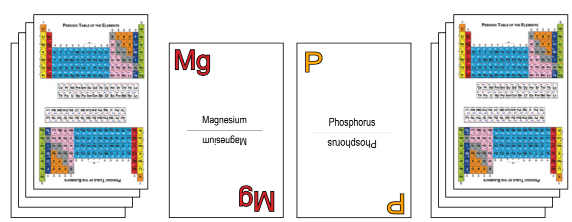
Noble gases (lime green, two of each): He, Ne, Ar, Kr, Xe

Deal: Each player receives half of the shuffled deck face down in front of them. Players will have 22 cards each.

Object of the game: To capture the most cards by comparing the absolute value of ions formed.

Play: Players turn over their top card and lay it face up. Both players say the ion the Element card forms. Referring to the periodic table may be necessary. The player who has the card bearing the Element card with the higher absolute value ion wins, that is, whichever element gains or loses the most electrons.

For example, in P^{3-} versus Mg^{2+}, the P^{3-} wins both cards. Make sure that both players agree to the results. The two cards are placed in a separate winnings pile for each player.



Magnesium forms Mg^{2+} and phosphorus forms P^{3-}. The card on the right, phosphorus, wins since it forms a 3^- charge, which is larger than a 2^+ charge.

If the Elements turned over form the same ion charge, a war is declared. Each player turns up one card face down and one card face up. The player with the higher ion takes all six cards.

Variation: Play Ion War Part One, but score using the actual ion values, not the absolute values. In this case, Mg^{2+} would be greater than P^{3-} since $^+2$ is greater than $^-3$.

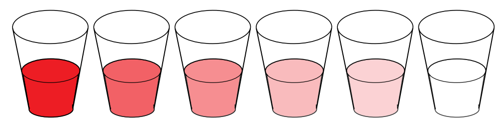
CONCENTRATION (C)

People interact with solutions many times a day usually without thinking about it. Solutions are essential to life from the air we breathe to the beverages we drink. In medicine, it is especially critical to have the correct solution for a patient's treatment.

A solution consists of a solute and a solvent. The solute is the lesser amount or component that changes phase, while the solvent is the larger amount. With many solutions, the solvent is water. Another name for water is the *universal solvent*, because so many different things can be dissolved in it.

Kool-Aid™ is a solution. The solute is the powder and sugar and the solvent is water. Soda is also a solution with the solutes being carbon dioxide gas and soda flavoring. Again, the solvent is water.

The image to the right shows six different concentrations of Kool-Aid™ . The amount of solute varies in each one of these solutions, but the volume of the solution is the same which leads to the varying shades of Kool-Aid™ . The different concentrations can be appreciated not only by your eye, but also by your taste buds.



The most concentrated solution of Kool-Aid™ is on the left.

Concentration expresses how much solute is present in a given amount of solvent. Common examples of concentration are shown in the table: (m/m)%, (v/v)%, (m/v)%, and molarity.

Often, the solute is listed after the concentration. For example, the Kool-Aid™ concentration would be given as 0.696 M of sugar. The abbreviation M stands for molarity, which has units of mol/L. A greater number listed in front of a concentration means a more concentrated solution or more moles of solute. A concentration of 0.696 M can be used as a conversion factor shown below:

$$\frac{0.696\text{ mol}}{1\text{ L}} \begin{matrix}\leftarrow \text{numerator}\\ \leftarrow \text{denominator}\end{matrix}$$

CONCENTRATION
Molarity = $\dfrac{\text{moles of solute}}{\text{L of solution}}$
Mass percent = (m/m)% $\dfrac{\text{mass}_{\text{solute}}}{\text{mass}_{\text{solute}} + \text{mass}_{\text{solvent}}} \times 100\%$
Volume percent = (v/v)% $\dfrac{\text{volume}_{\text{solute}}}{\text{volume}_{\text{solute}} + \text{volume}_{\text{solvent}}} \times 100\%$
Mass/volume = percent (m/v)% $\dfrac{\text{mass}_{\text{solute}}}{\text{volume}_{\text{solute}} + \text{volume}_{\text{solvent}}} \times 100\%$

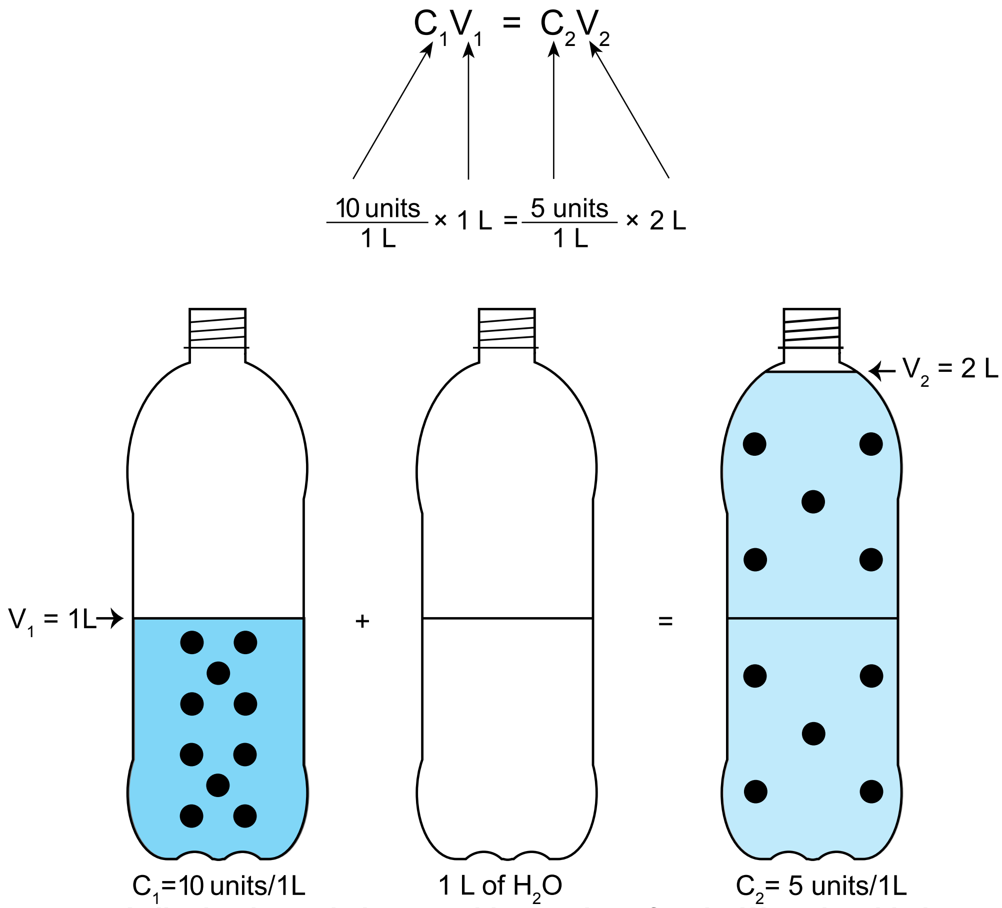
Making several solutions of different concentrations can be time consuming; however, using dilution or serial dilution can greatly reduce the amount of time required. Instead of weighing out a specific amount of Kool-Aid™ powder and sugar for each one of the solutions above, a concentrated solution is prepared. A volume of the concentrated solution is then transferred to another cup that contains increasing amounts of solvent, thereby decreasing the amount of solute in a given volume. The dilution formula is shown below. Note that concentration and volume are inversely related. As volume increases, concentration decreases and as volume decreases, concentration increases.

$$C_1V_1 = C_2V_2$$

initial concentration (C_1)
initial volume (V_1)
final concentration (C_2)
final volume (V_2)

To help understand this concept, imagine you have 1 L of soda with 10 dissolved units and dilution is performed. The units are represented by the large black circles in the image below.

One liter of water is added to the soda, and now the 10 dissolved units have more space between them. Applying the dilution equation will illustrate what is going on in the solution.



A dilution is carried out on this solution of soda. Water is added to make the new volume 2 L.

As concentration decreases, volume increases. The solution on the left has a concentration of 10 units per 1 L, while the solution on the right has a concentration of 5 units per 1 L. The volume increased from 1 L on the left to 2 L on the right.

With dilutions, $C_1 > C_2$ (the final concentration of 5 units/L is less than the initial concentration of 10 units/L) and $V_2 > V_1$ (the final volume of 2 L is greater than the initial volume of 1 L), will always be the case. Additionally, the amount of solvent added can be determined by subtracting the initial volume from the final volume:

$$\text{Volume}_{\text{solvent}} = V_2 - V_1$$

The first few games are aimed at calculating concentrations and later ones focus on dilution. As the games progress, more emphasis is placed on unit cancellation and the games use more Conversion cards and Prompt cards.

C1 Concentration War: Mass/Volume Percent

Objective: To practice finding mass volume percent (m/v)% concentrations using fraction simplification.

Background: Mass/Volume percent is one of the few concentrations where the numerator and denominator have different units of measurement.

$$\text{Mass volume percent (m/v)\%} = \frac{\text{mass}_{\text{solute}}}{\text{volume}_{\text{solute}} + \text{volume}_{\text{solvent}}} \times 100\%$$

The denominator in the above equation is the volume of solution. The amount of solution is equal to the amount of solute plus the amount of solvent.

solution = solute + solvent

Number of players: Two, sitting on the same side of the table.

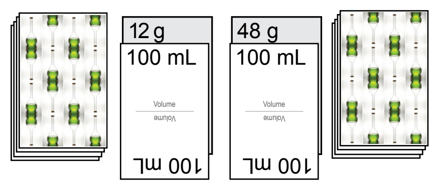
Manipulatives: Paper and pencil.

Cards: Two of each of the Mass cards with units of grams with the 454 g card removed, 28 cards total. Two 100 mL cards from Volume cards.

Deal: Set a 100 mL card in front of each player. Each player receives half of the Mass deck face down.

Object of the game: To capture the most cards using 100 mL of solution as the denominator. The player with the higher concentration takes both cards.

Play: Both players turn over the top solute card of their stack. Players perform the division mentally and state the (m/v)% concentration aloud. For example, 8 g solute per100 mL solution is stated as 8% (multiply by 100%). The player with the greater mass/volume concentration collects the two cards. The 100 mL of solution card remains as the denominator throughout the game for each player.



The mass/volume percent on the right wins 48% (m/v) is higher than 12% (m/v) on the left.

If the concentrations are equal, a war is declared. Each player places one card face down. Then the players form another concentration face up and state the answers. The player with the higher concentration captures all the cards. Players compare the height of their winnings pile to determine the winner.

Variation: Use the 200 mL card as a denominator. Return the 100 mL cards to the playing deck. For example, 24 g/200 mL is stated as 12%.

C2 New Concentration War after Solvent Add: Mass/Volume Percent

Objective: To practice finding mass/volume percent (m/v)% concentrations after solvent is added.

Background: In C1 Concentration War: Mass/Volume Percent above, mass/volume percent was covered. In this game, additional solvent is being added and the new concentration is compared for war. Recall:

solution = solute + solvent.

In this game, solvents will be added to the volume, the denominator in the equation.

Number of players: Two, sitting on the same side of the table.

Manipulatives: Paper and pencil.

Cards: All of the Mass cards showing units of grams (g); remove the 454 g card, total of 28 cards. Volume cards (8 mL to 200 mL and 0.006 L to 0.200 L), for 30 cards total.

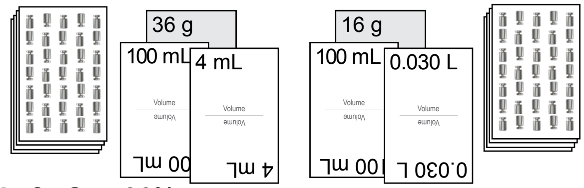
Deal: Set a 100 mL card in front of each player. Each player receives half of each deck, Volume and Mass, in two piles face down.

Object of the game: To capture the most Mass cards after calculating the new concentration after the solvent has been added.

Play: Both players turn over the top card of the Mass stack. The 100 mL of solution card remains as the initial volume of solution throughout the game for each player. Players divide the Mass card by the 100 mL card, multiply by 100%, and state their initial (m/v)% concentration.

Players turn over a Volume card. This is the amount of solvent added. Players add the solvent amount to their 100 mL card and recalculate the (m/v)% concentration. The player with the higher new concentration collects both of the Mass cards.

If the new concentrations are equal, a war is declared. Each player turns over three more cards, two Volume cards and one Mass card. The player with the higher new concentration captures all the cards. The game continues until one player has captured most of the cards.



Left: C_1 = 36%

$volume_{solution}$ = 100 mL + 4 mL = 104 mL

C_2 = 36 g/104 mL × 100% = 34.]6 → 35%

Right: C_1 = 16%

$volume_{solution}$ = 100 mL + 0.030 L = 130 mL

C_2 = 16 g/130 mL × 100% = 12.]3 → 12%

C3 Solvent War: Volume/Volume

Objective: To practice finding solvent volumes by subtracting the solute volume from the solution volume.

Background: For calculations involving concentration, regardless of the type of concentration being calculated, the standard setup is as follows: amount of solute in the numerator and amount of solution in the denominator. The amount of solution is the amount of solute plus the amount of solvent. This game prepares for calculating volume/volume percent by identifying solute, solvent, and solutions.

$$\text{Volume}_{solution} = \text{volume}_{solute} + \text{volume}_{solvent}$$

or

$$\text{Volume}_{solvent} = \text{volume}_{solution} - \text{volume}_{solute}$$

Number of players: Two, sitting on the same side of the table.

Manipulatives: Paper and pencil.

Cards: Volume cards in units of mL and cm^3: 37 total.

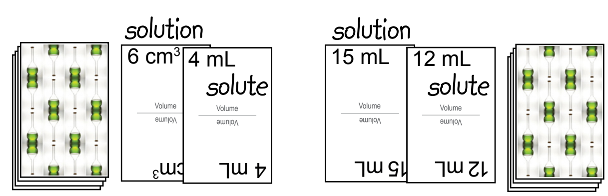
Deal: Randomly select and remove a card. Each player receives half of the remaining deck face down.

Object of the game: To capture the most cards by having the largest volume of solvent given the volume of solute and the volume of solution. The player with the larger volume of solvent takes both cards.

Play: Both players turn over two volume cards. The larger volume is the solution and the smaller volume is the solute. If a player draws the same two volumes out of their stack, they replace one of the same cards with another volume and place the duplicate card at the bottom of their stack.

Players calculate the volume of the solvent by subtracting the volume of the solute from the volume of the solution. The player with the larger volume of solvent captures all the cards.

If the solvent volumes are equal, a war is declared. The player with the larger solvent volume captures all the cards. Players compare the height of their winnings pile to determine the winner.



Left: $volume_{solvent}$ = 6 cm^3 – 4 mL = 2 mL

Right: $volume_{solvent}$ = 15 mL – 12 mL = 3 mL

The player on the right wins this war.

C9 Final Volume Peace

Objective: To reinforce the dilution equation by determining the simplest volumes required of both the initial and final concentrations.

Background: The formula for dilution is:

$$C_1V_1 = C_2V_2$$

C_1: **initial concentration**; V_1: **initial volume**; C_2: **final concentration**; V_2: **final volume**

Note that concentration and volume are inversely related. As volume increases, concentration decreases and as volume decreases, concentration increases. This game reviews the relationships of concentration and volume.

Number of players: Two, sitting on the same side of the table.

Manipulatives: Paper, pencil, and centimeter cubes.

Cards: The 13 Conversion cards with units of mol/L. Remove the single 20 mol/L card, which will not be used.

Deal: Shuffle the cards. Set the cards between both players face down in one pile.

Object of the game: To collect the least amount of centimeter cubes.

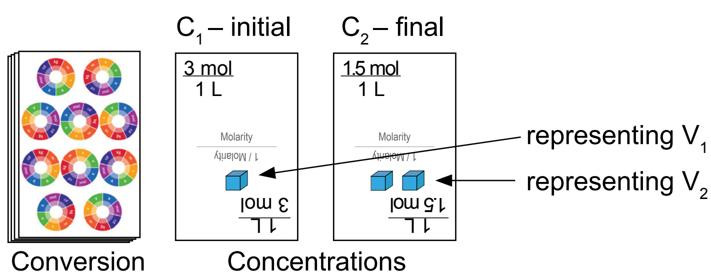
Play: Players alternate turning over two concentration cards. The higher concentration goes on the left. The higher concentration represents the initial concentration, C_1, and the lower concentration represents the final concentration, C_2. Place centimeter cubes on each card until:

$$C_1 \times \text{number of centimeter cubes} = C_2 \times \text{number of centimeter cubes}$$

Make certain that the simplest number of centimeter cubes are used.

Players collect the centimeter cubes that they place on the final concentration card (C_2). The centimeter cubes on the initial concentration card are discarded.

After all the cards have been turned over, shuffle the cards and play one more time through the stack. The player with the fewer number of cubes after the second round wins.



3 mol/L × 1 L = 1.5 mol/L × 2 L
3 mol = 3 mol
The player collects the two centimeter cubes from the final concentration card.

INDEX