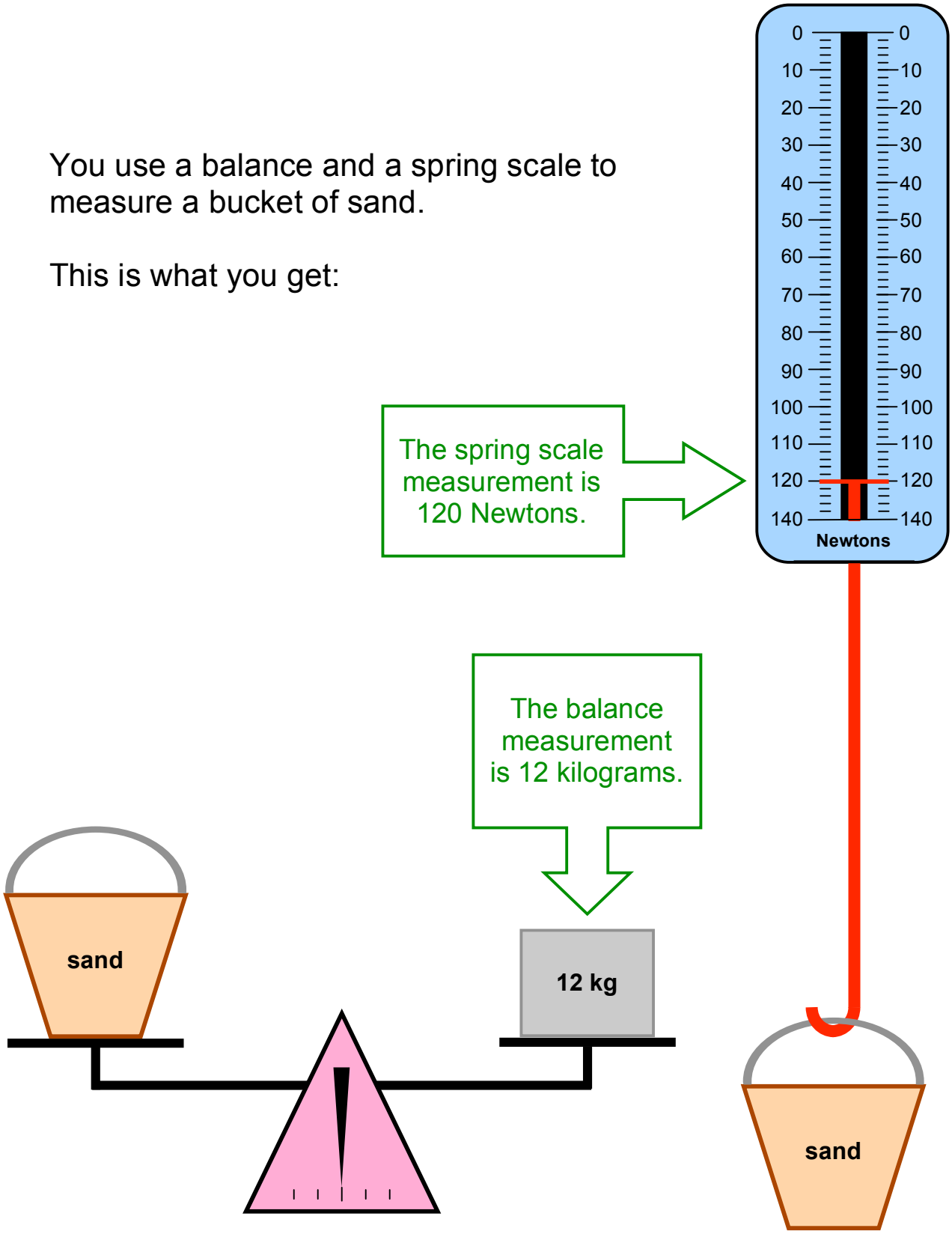
You use a balance and a spring scale to measure a bucket of sand.

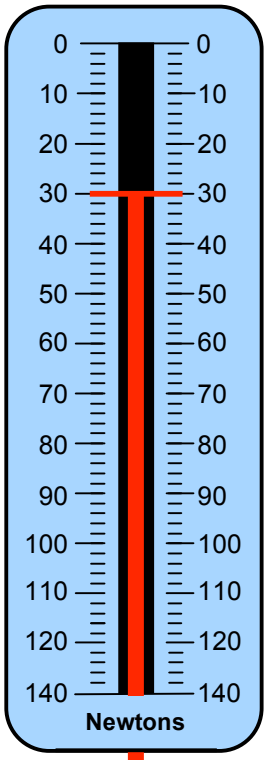
This is what you get:

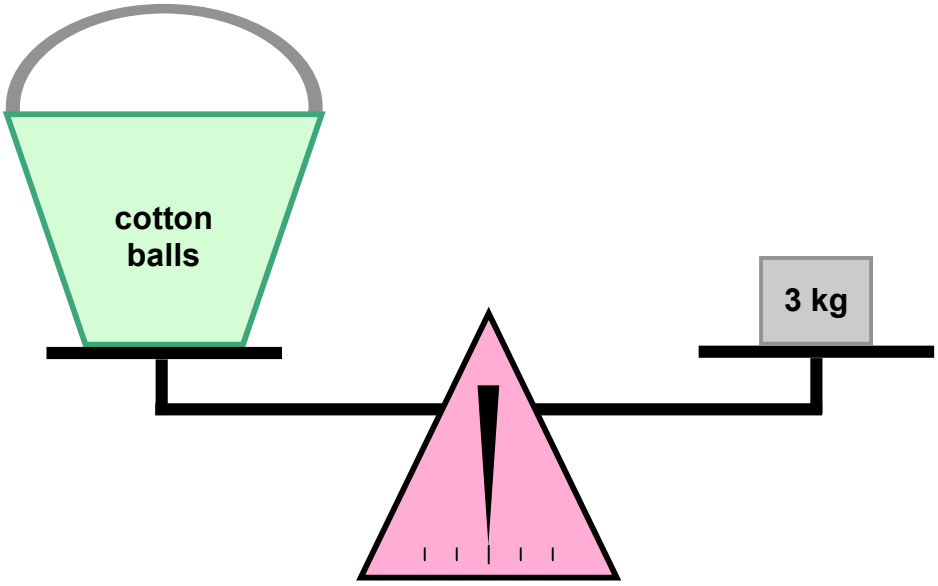


You use the same instruments to measure a bucket of cotton balls.

This is what you get:

balance measurement	spring scale measurement

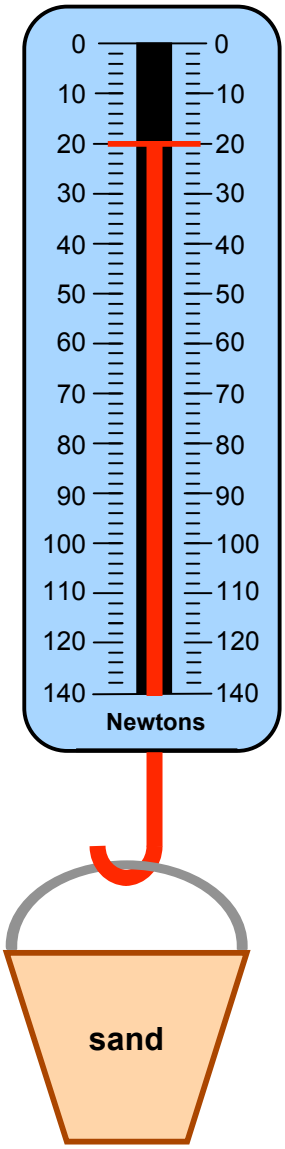


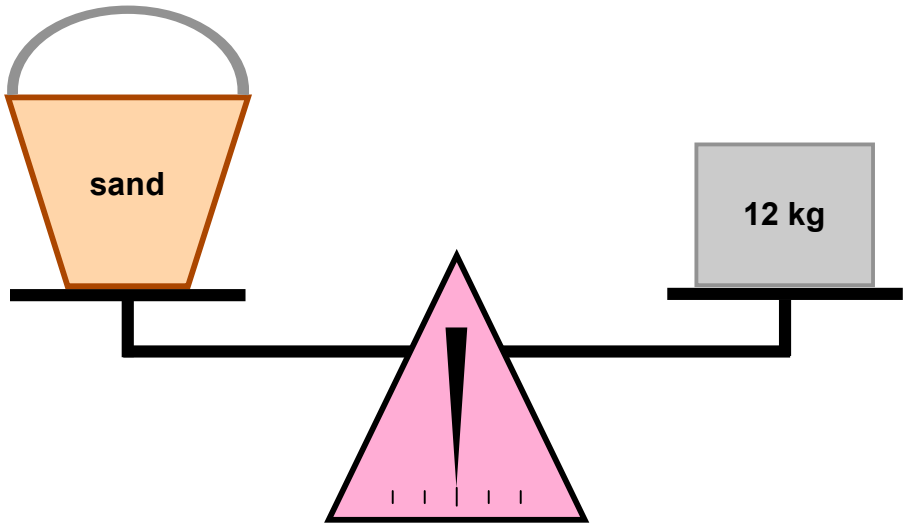


Next, you travel to the moon and measure everything again.

This is what you get for the bucket of sand on the moon:

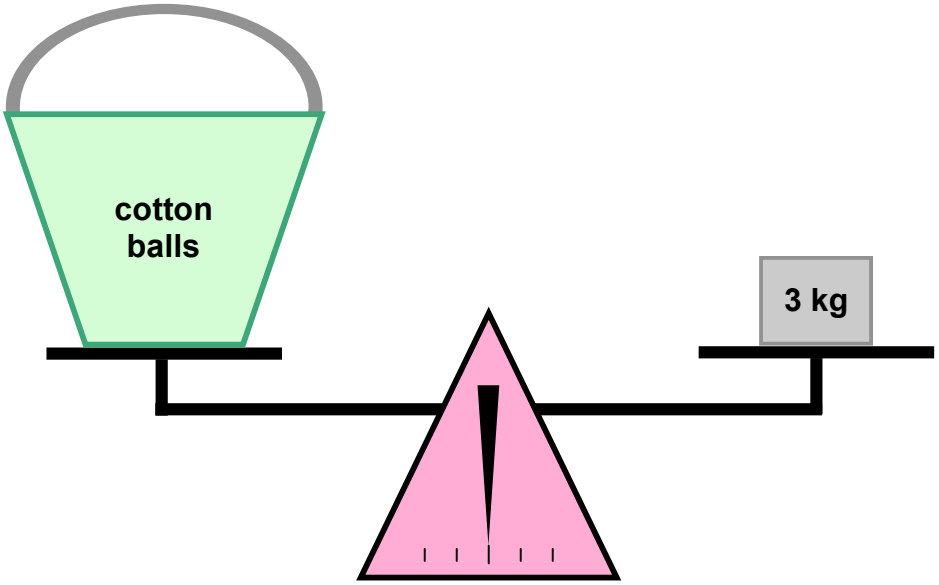
balance measurement	spring scale measurement

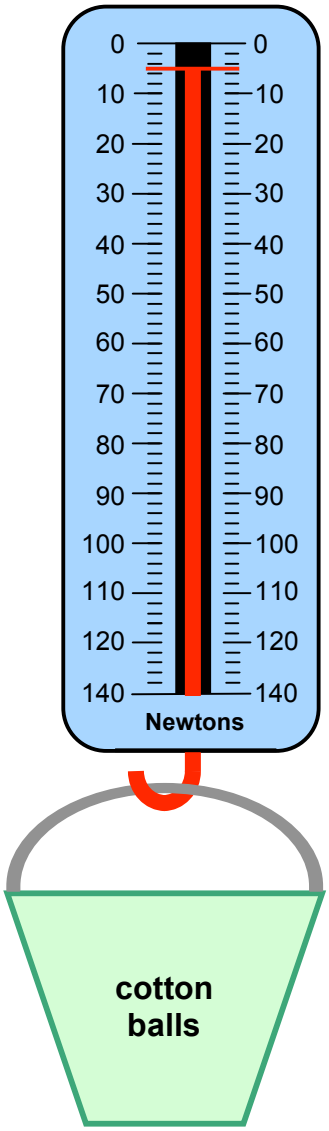




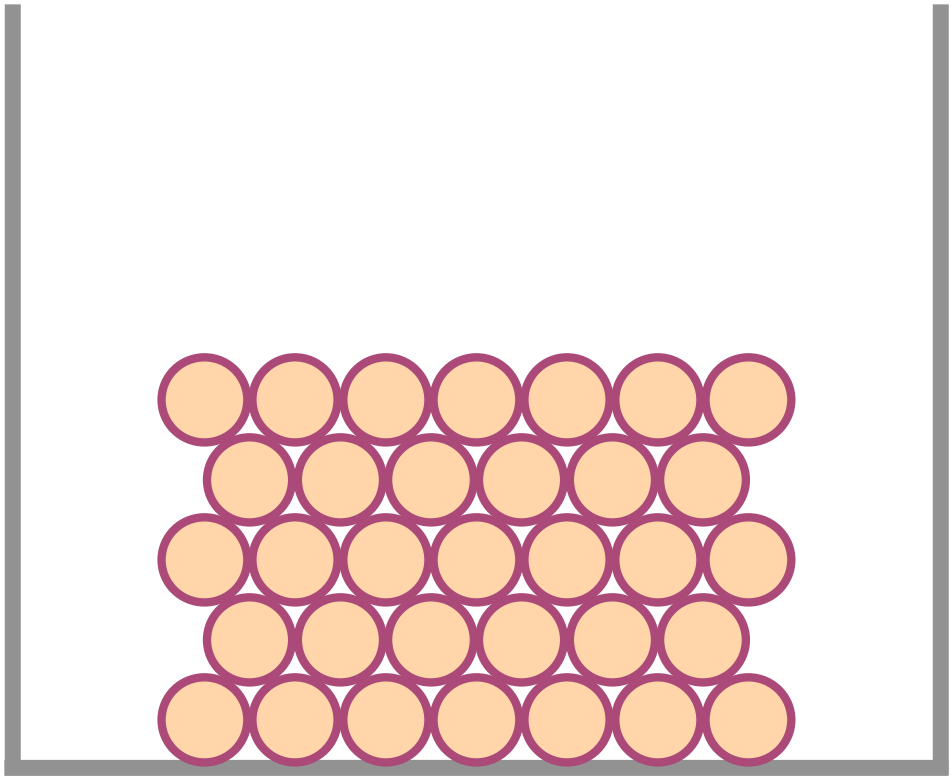
This is what you get for the bucket of cotton balls on the moon:

balance measurement	spring scale measurement

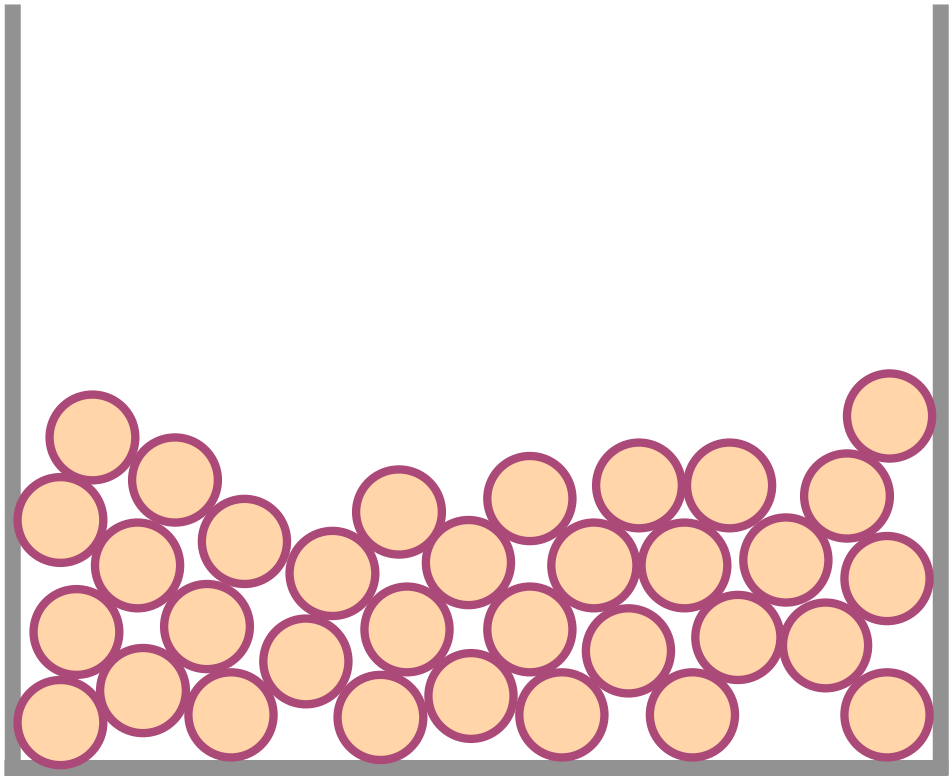




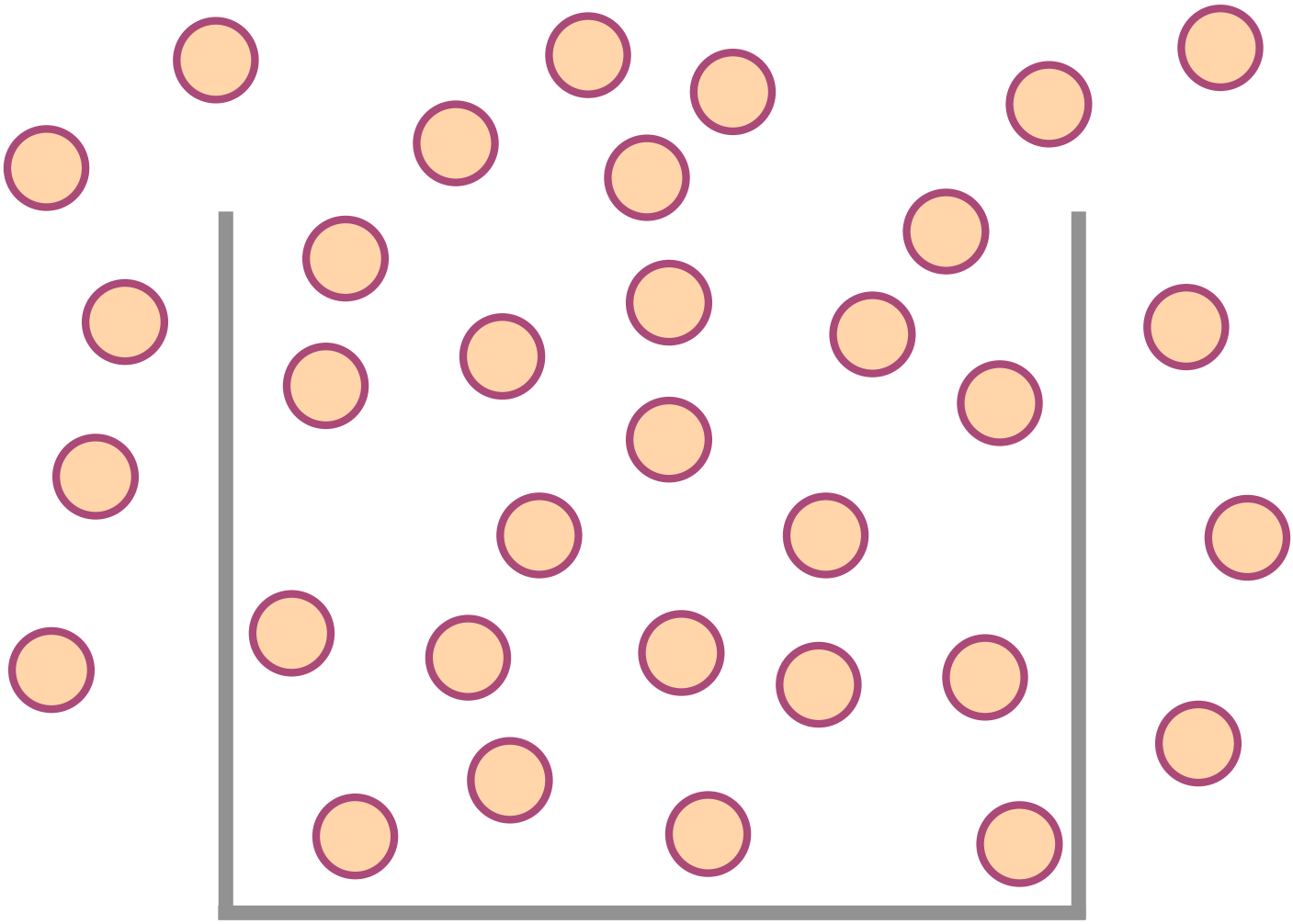
Substance	Sample Size	Mass	Volume	
water	whole	1200 g	1200 ml	
water	half	600 g	600 ml	
water	quarter	300 g	300 ml	
clay	whole	140 g	80 cc (or cm^3)	
clay	half	70 g	40 cc	
clay	quarter	35 g	20 cc	



The particles that make up a solid move slowly, so the attractions between particles pull them tightly together. Each particle becomes part of a fixed structure. As a result, particles of solids can vibrate and wiggle in place, but they can't move out of position.



The particles that make up a liquid move faster than the particles of solids. The attractions between particles pull them near each other, but the particles are able to slide past each other and move around. The particles move in random directions, but they tend to stay close enough to touch each other. It is hard to predict the path a given particle will follow, because it depends on the movements and positions of the particles around it.

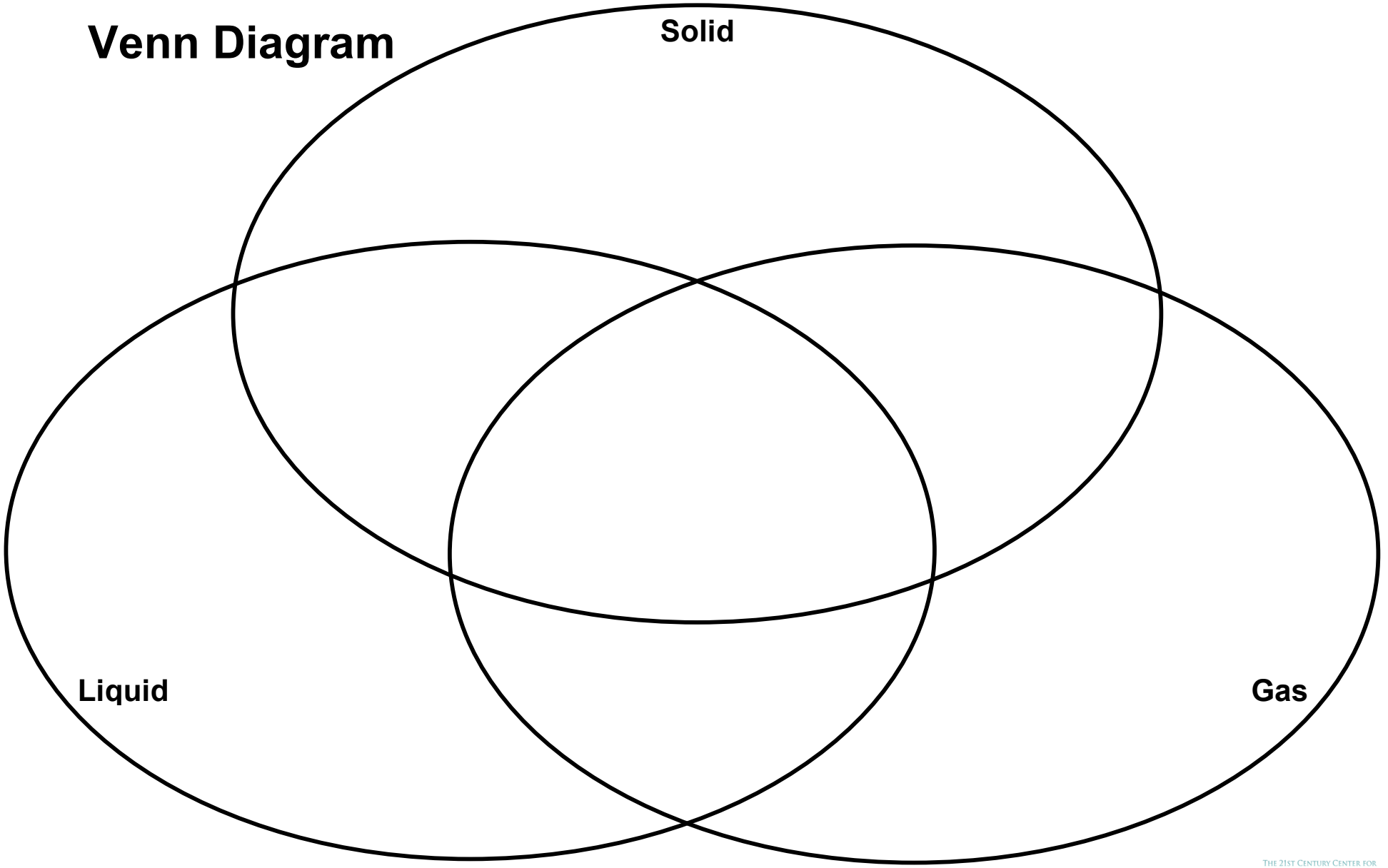


The particles that make up a gas move very fast, so the attractions between particles have little effect. The particles are free to move away from each other, so gases contain a lot of empty space. As in liquids, the direction of movement is random. Each particle moves in a straight line until it hits something and changes direction. The difference is that gas particles move very fast and spread out in all directions.

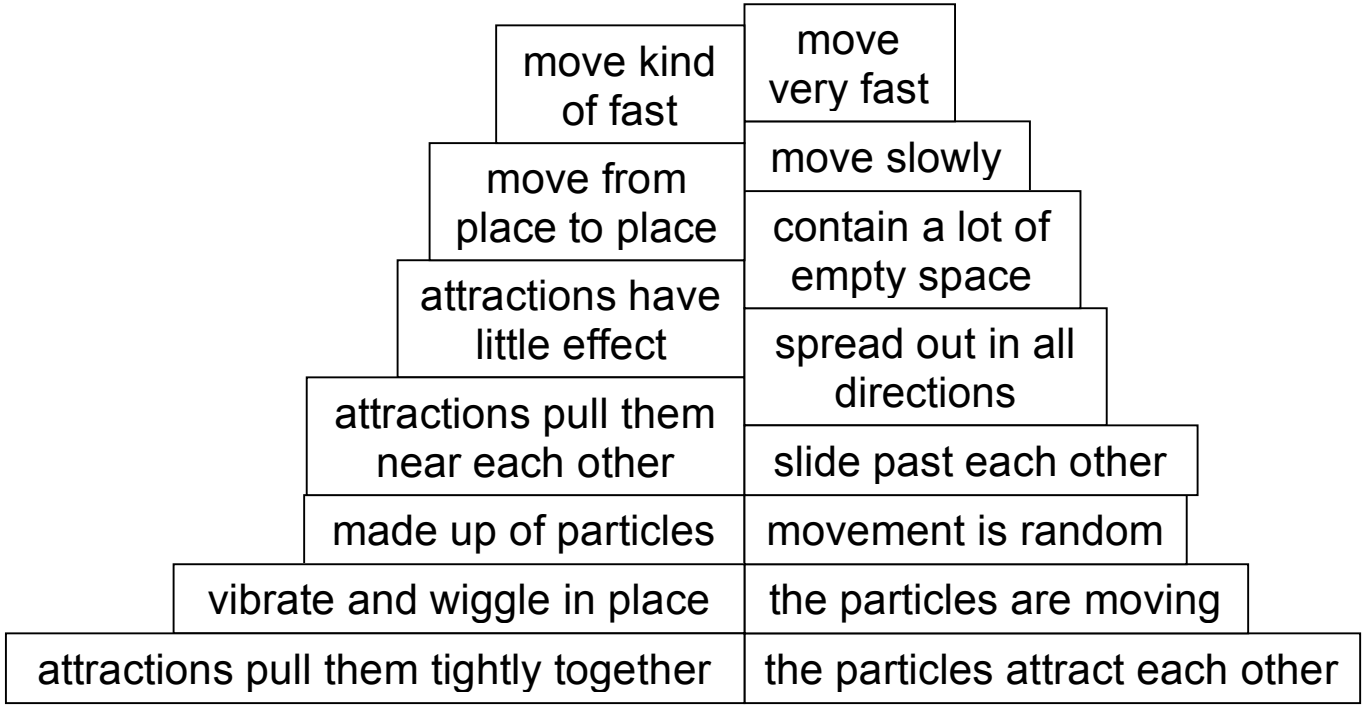
Data Table

	solid	liquid	gas
Is it made up of particles?			
Are the particles moving?			
If so, how fast do they move?			
Do the particles move from place to place or do they move in one place?			
If they move from place to place, is the movement random or does it follow a pattern?			
Do the particles attract each other?			
If so, what effect do the attractions have on the particles?			

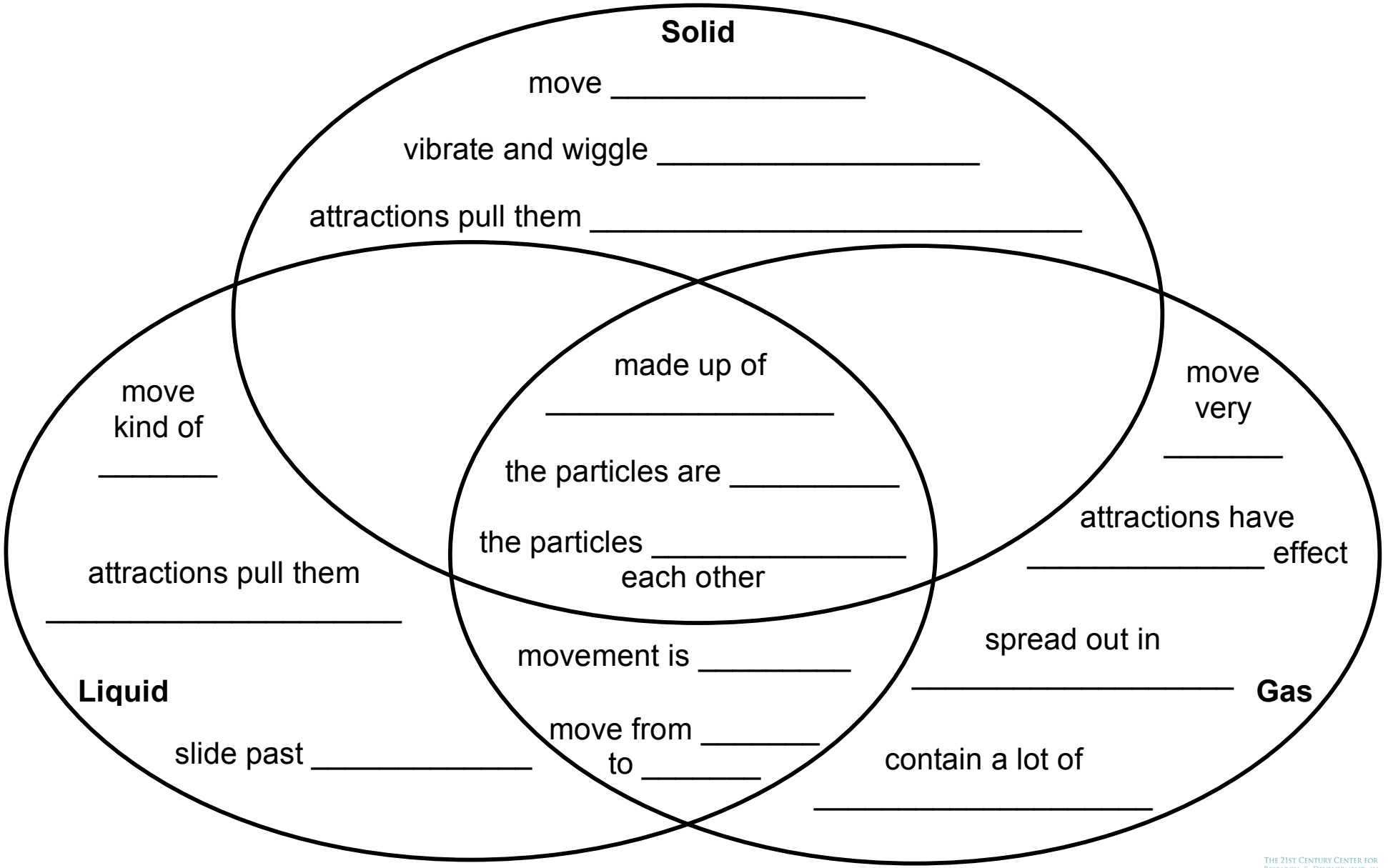
Venn Diagram



Compare Particle Models



Compare Particle Models



Oxygen — Element

Oxygen makes up about one fourth of the mass of the air we breathe, two thirds of the human body, and nine tenths of water. It combines with most elements, and it is a part of hundreds of thousands of compounds. When oxygen is a gas, it has no color, odor, or taste. When it is a liquid or solid, it is pale blue. Humans and many other organisms would die without oxygen because our cells use it to convert stored energy to usable energy. We can survive for weeks without food and for days without water, but we can't survive for more than a few minutes without oxygen.

Chemical Symbol:	O	Usual State:	gas
Atomic Mass:	16 amu	Melting Point:	-219°C
Category:	nonmetal	Boiling Point:	-183°C
*Density:	0.0014 g/cm^3		

*at 20ºC and 1.0 atm

Hydrogen — Element

Hydrogen is the lightest and most abundant of all the elements, but it doesn't exist naturally on earth. It is found only as a part of compounds. For example, water is made up of two parts hydrogen to one part oxygen. Hydrogen gas is colorless, odorless, and highly flammable. It is fourteen and a half times lighter than air, and for some time it was used in lighter-than-air balloons. After the Hindenburg disaster, hydrogen-lifted airships were abandoned as too dangerous, but researchers are now trying to develop ways to use hydrogen as a safe, clean, and cost-effective energy source.

Chemical Symbol:	H	Usual State:	gas
Atomic Mass:	1 amu	Melting Point:	-260°C
Category:	nonmetal	Boiling Point:	-253°C
*Density:	0.0001 g/cm^3		

*at 20ºC and 1.0 atm

Sodium — Element

Sodium is a soft, bright, silvery-white metal. It is so soft that it can be easily cut with a knife. Compounds of sodium are very common, but the metal itself is never found free in nature. Pure sodium metal is not very useful since it reacts explosively with water, but sodium is a part of a wide variety of important compounds. The most common is sodium chloride, which is essential to human and animal nutrition.

Chemical Symbol:	Na	Usual State:	solid
Atomic Mass:	23 amu	Melting Point:	98°C
Category:	metal	Boiling Point:	883°C
*Density:	0.97 g/cm^3		

*at 20ºC and 1.0 atm

Chlorine — Element

Chlorine is a greenish-yellow gas that is highly irritating to the lungs and can be fatal. In fact, it was used as a weapon in World War I. Liquid chlorine can burn the skin. Chlorine is rarely found free in nature. Because it can combine with almost all the other elements, it is a part of many different compounds. The most common chlorine compound is salt, which consists of one part chlorine to one part sodium. Chlorine is widely used as a disinfectant and bleaching agent, and it is used to produce safe drinking water all over the world.

Chemical Symbol:	Cl	Usual State:	gas
Atomic Mass:	35 amu	Melting Point:	-102°C
Category:	nonmetal	Boiling Point:	-34°C
*Density:	0.0032 g/cm^3		

*at 20ºC and 1.0 atm

Water Compound

Every particle of water is made up of two particles of hydrogen and one particle of oxygen. Water is a compound, but it can also be part of other compounds. It is the only natural substance that can be found in all three states at the temperatures normally found on Earth, and it is the baseline for the Celsius temperature scale: 0ºC is water's freezing point and 100ºC is its boiling point. Another unique thing about water is that ice is less dense than liquid water. For most substances, the solid form is more dense than the liquid form.

Chemical Formula:	H_2O	Usual State:	liquid
*Density:	1.00 g/cm^3	Melting Point:	0°C
		Boiling Point:	100°C

*at 20ºC and 1.0 atm

Salt Compound

Every particle of salt is made up of one particle of sodium and one particle of chlorine. Also called sodium chloride, salt occurs naturally in many parts of the world as the mineral halite. Salt crystals, which are cube-shaped, are often used as an example of crystalline structure. It is one of the few minerals that people eat, and it is commonly used as a food preservative. Salt is an essential nutrient for humans and other animals because it regulates the body's water content, helps control heart rhythm and blood pressure, and helps brain and nerve cells function properly.

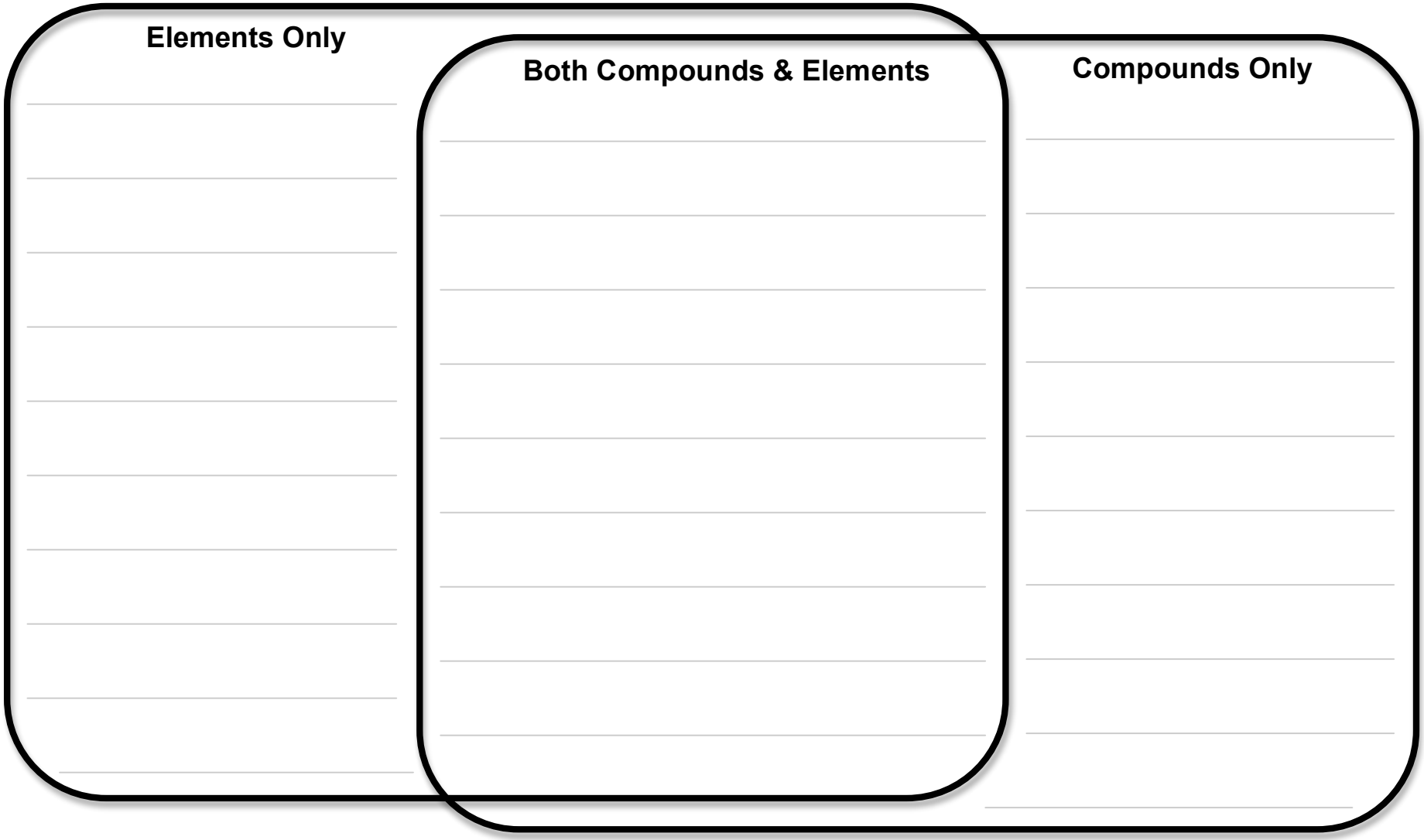
Chemical Formula:	NaCl	Usual State:	solid
*Density:	2.17 g/cm^3	Melting Point:	801°C
		Boiling Point:	1465°C

*at 20ºC and 1.0 atm

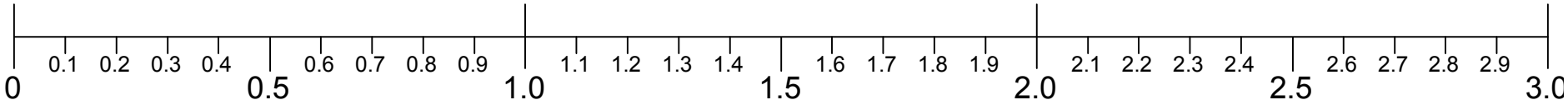
Compare Elements & Compounds – Data Table 16

	oxygen	hydrogen	sodium	chlorine	water	salt
Is it an element or compound?						
Does it combine with elements?						
Is it part of one or more compounds?						
Is it made up of particles of other substances?						
If so, what kind? (elements or compounds)						
What kind of chemical representation does it have? (symbol or formula)						
Is its density less than 0.01 g/cm^3?						
What is its usual state?						

Compare Elements & Compounds – Venn Diagram 17



Compare Elements & Compounds – Density Scale



Material	Density (g/cm^3)
oxygen	0.0014
hydrogen	0.0001
sodium	0.97
chlorine	0.0032
water	1.00
salt	2.17
modeling clay	1.75
wood (cypress)	0.50
honey	1.40

Carbon Dioxide — Compound

Every particle of carbon dioxide is made up of one particle of carbon and two particles of oxygen. The solid form of carbon dioxide is called dry ice because it changes directly from solid to gas without going through a "wet" liquid stage. Carbon dioxide gas is colorless, and it is a small but important part of the air around us. Green plants need carbon dioxide for photosynthesis, the process they use to produce sugar. Carbon dioxide is a by-product of many chemical processes, including the reaction between vinegar and baking soda, the burning of fossil fuels, and the process our cells use to convert sugar to usable energy.

Chemical Formula:	CO_2	Usual State:	gas
*Density:	.0020 g/cc	Melting Point:	-78°C
		Boiling Point:	-57°C

*at 20ºC and 1.0 atm

Baking Soda — Compound

Every particle of baking soda is made up of one particle of sodium, one particle of hydrogen, one particle of carbon, and three particles of oxygen. Also called sodium bicarbonate, baking soda is a white, crystalline solid that often appears as a fine powder. It is mainly used in baking because it reacts with acidic ingredients like vinegar or lemon juice to release carbon dioxide, creating bubbles that make baked goods light and fluffy. Baking soda is also useful as a cleaner, deodorizer, antacid, and fire extinguisher. Above 70°C, baking soda gradually breaks down into simpler compounds.

Chemical Formula:	$NaHCO_3$	Usual State:	solid
*Density:	2.16 g/cc	Melting Point:	70°C
		Boiling Point:	none

*at 20ºC and 1.0 atm

Sucrose — Compound

Every particle of sucrose is made up of 12 particles of carbon, 22 particles of hydrogen, and 11 particles of oxygen. Commonly called sugar, sucrose is a white, crystalline powder with a sweet taste. Sucrose and other sugars are made by green plants through a process called photosynthesis. Most sucrose comes from sugar cane, but it is also obtained from sugar beets, sorghum, and sugar maple trees. It is easily digested and provides a quick source of energy, but eating too much sugar can cause tooth decay and other health problems. At 185°C, sucrose melts and breaks down to form simpler compounds.

Chemical Formula:	$C_{12}H_{22}O_{11}$	Usual State:	solid
*Density:	1.59 g/cc	Melting Point:	185°C
		Boiling Point:	none

*at 20ºC and 1.0 atm

Acetic Acid — Compound

Every particle of acetic acid is made up of two particles of carbon, four particles of hydrogen, and two particles of oxygen. It is a colorless liquid with a sour taste, and it is the main ingredient in vinegar. Pure acetic acid can cause painful burns, but most vinegar is only about 5% acetic acid. Despite this low concentration, vinegar retains many of acetic acid's useful properties. It dissolves mineral deposits, so it can be used to remove hard water stains. It inhibits the growth of bacteria, so it can be used as a food preservative and as a mild disinfectant in cleaning. And its sour taste makes it a popular flavoring in cooking and salad dressings.

Chemical Formula:	$C_2H_4O_2$	Usual State:	liquid
*Density:	1.05 g/cc	Melting Point:	17°C
		Boiling Point:	118°C

*at 20ºC and 1.0 atm

Salt-and-Pepper — Mixture

Because many recipes call for both salt and pepper, some people keep a shaker filled with a mixture of the two. One popular combination is three parts salt to one part pepper, but the ratio can be adjusted according to taste. Most salt-and-pepper mixtures contain table salt and black pepper, but some people prefer sea salt or red pepper flakes. The density of the mixture depends on the kinds and amounts of salt and pepper it includes. The salt within the mixture will melt and boil at its usual temperatures. Pepper is a dried fruit, and its melting and boiling points depend on the elements and compounds that make up the fruit.

*Density:	varies (average=1.64 g/cc)	Usual State:	solid
		Melting Point:	varies
		Boiling Point:	varies

*at 20ºC and 1.0 atm

Air — Mixture

Air is mostly nitrogen and oxygen, with trace amounts of carbon dioxide, water vapor, and other gases. The composition of air changes from place to place and time to time. For example, air near a lot of green plants has more oxygen and less carbon dioxide than air in a desert or above the ocean. Similarly, air near cities contains less oxygen and more carbon dioxide and other gases than air in rural areas. And humid air contains more water vapor and less nitrogen, oxygen, and other gases than dry air. The density of air depends on its composition, and the elements and compounds that make up air will change state at their usual temperatures.

*Density:	varies (average=0.0012 g/cc)	Usual State:	gas
		Melting Point:	varies
		Boiling Point:	varies

*at 20ºC and 1.0 atm

Compare Compounds & Mixtures – Data Table 22

	carbon dioxide	baking soda	sucrose	acetic acid	salt & pepper	air
Is it a compound or mixture?						
Is it made up of particles of other substances?						
If so, what kind? (elements, compounds, both)						
Does it have a chemical formula?						
What is its usual state?						
Does it have a definite density?						
Does it have a definite melting point?						
Does it have a definite boiling point?						

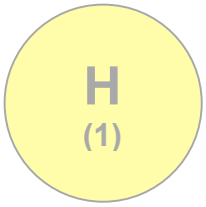
Compare Compounds & Mixtures – Venn Diagram

Oxygen — Atom

Chemical Symbol:	O	Usual State:	gas
Atomic Mass:	16 amu	Melting Point:	-219°C
Category:	nonmetal	Boiling Point:	-183°C
*Density:	0.0014 g/cm^2		

*at 20ºC and 1.0 atm

Hydrogen — Atom



Chemical Symbol:	H	Usual State:	gas
Atomic Mass:	1 amu	Melting Point:	-260°C
Category:	nonmetal	Boiling Point:	-253°C
*Density:	0.0001 g/cm^2		

*at 20ºC and 1.0 atm

Sodium — Atom

Chemical Symbol:	Na	Usual State:	solid
Atomic Mass:	23 amu	Melting Point:	98°C
Category:	metal	Boiling Point:	883°C
*Density:	0.97 g/cm^2		

*at 20ºC and 1.0 atm

Chlorine — Atom

Chemical Symbol:	Cl	Usual State:	gas
Atomic Mass:	35 amu	Melting Point:	-102°C
Category:	nonmetal	Boiling Point:	-34°C
*Density:	0.0032 g/cm^2		

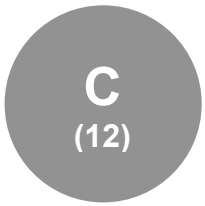
*at 20ºC and 1.0 atm

Nitrogen — Atom

Chemical Symbol:	N	Usual State:	gas
Atomic Mass:	14 amu	Melting Point:	-210°C
Category:	nonmetal	Boiling Point:	-196°C
*Density:	0.0013 g/cm^2		

*at 20ºC and 1.0 atm

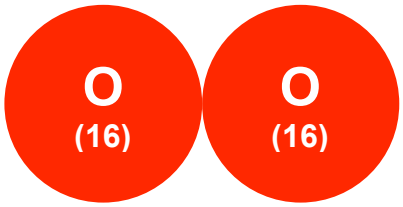
Carbon — Atom



Chemical Symbol:	C	Usual State:	solid
Atomic Mass:	12 amu	Melting Point:	3550°C
Category:	nonmetal	Boiling Point:	3825°C
*Density:	2.27 g/cm^2		

*at 20ºC and 1.0 atm

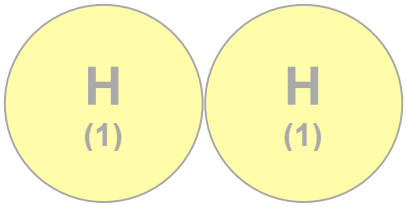
Oxygen — Molecule



Chemical Formula:	O_2	Usual State:	gas
*Density:	0.0014 g/cm^2	Melting Point:	-219°C
		Boiling Point:	-183°C

*at 20ºC and 1.0 atm

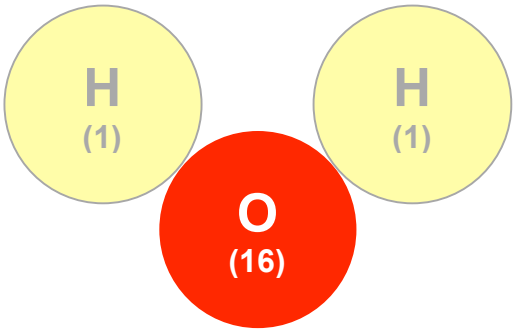
Hydrogen — Molecule



Chemical Formula:	H_2	Usual State:	gas
*Density:	0.0001 g/cm^2	Melting Point:	-260°C
		Boiling Point:	-253°C

*at 20ºC and 1.0 atm

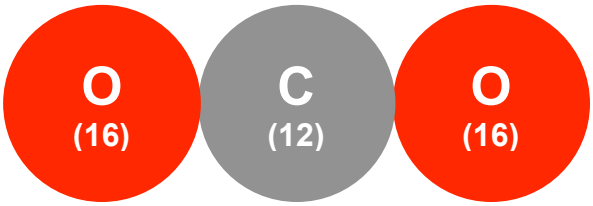
Water — Molecule



Chemical Formula:	H_2O	Usual State:	liquid
*Density:	1.00 g/cm^2	Melting Point:	0°C
		Boiling Point:	100°C

*at 20ºC and 1.0 atm

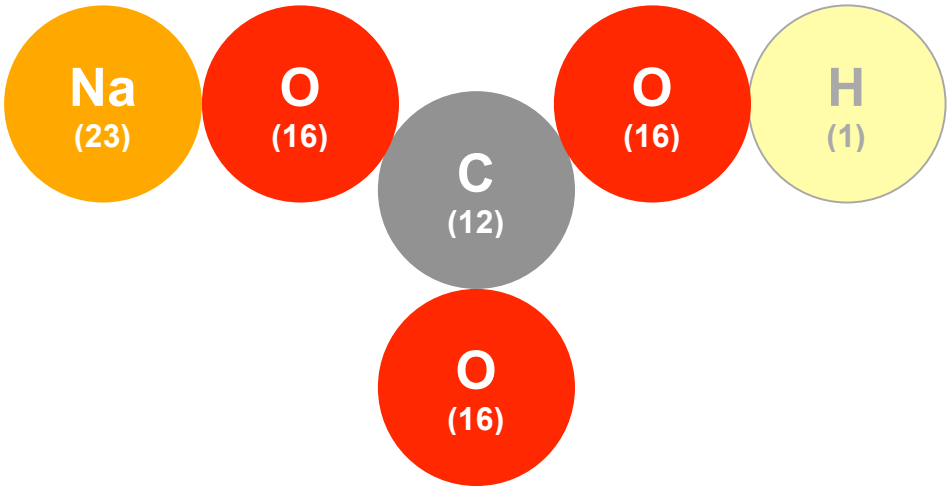
Carbon Dioxide — Molecule



Chemical Formula:	CO_2	Usual State:	gas
*Density:	.0020 g/cm^2	Melting Point:	-78°C
		Boiling Point:	-57°C

*at 20ºC and 1.0 atm

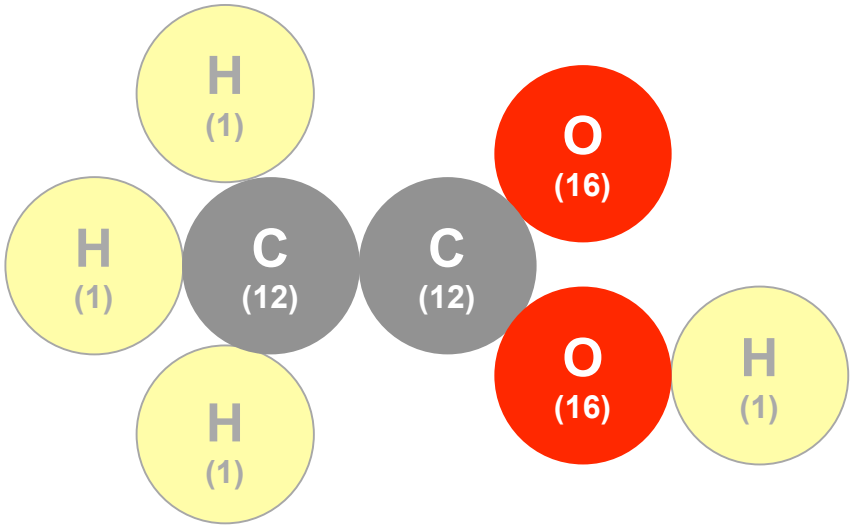
Baking Soda — Molecule



Chemical Formula:	$NaHCO_3$	Usual State:	solid
*Density:	2.16 g/cm^2	Melting Point:	70°C
		Boiling Point:	none

*at 20ºC and 1.0 atm

Acetic Acid — Molecule



Chemical Formula:	$C_2H_4O_2$	Usual State:	liquid
*Density:	1.05 g/cm^2	Melting Point:	17°C
		Boiling Point:	118°C

*at 20ºC and 1.0 atm

Compare Atoms & Molecules – Data Table 1

	oxygen	hydrogen	sodium	chlorine	nitrogen	carbon
Is it an atom or molecule?						
Is there one circle or more than one?						
Does it have a symbol or formula?						
Does it have atomic mass?						
Does it have density?						
What is its usual state?						
Is it an element, compound, or mixture?						

	oxygen	hydrogen	water	carbon dioxide	baking soda	acetic acid
Is it an atom or molecule?						
Is there one circle or more than one?						
Does it have a symbol or formula?						
Does it have atomic mass?						
Does it have density?						
What is its usual state?						
Is it an element, compound, or mixture?						

Compare Atoms & Molecules – Venn Diagram