Name: ______________________________

## Skill Sheet 16 Indirect Measurement

Have you ever wondered how scientists and engineers measure large quantities like the mass of an iceberg, the volume of a lake, or the distance across a river? Obviously, balances, graduated cylinders, and measuring tapes could not do the job! Very large (or very small) quantities are calculated through a process called indirect measurement. This skill sheet will give you an opportunity to try indirect measurement for yourself.

### 1. Using a shadow to find the height of a tree

Try this activity on a sunny day. You will need two meter sticks, a calculator, pencil and paper, and a tall tree to measure. (If there are no trees nearby, substitute a building, flagpole, statue, or other tall outdoor object.)

Ask a friend to hold the meter stick vertically, with one end touching the ground. Measure and record the length of the shadow formed by the meter stick.

An object twice as tall as the meter stick will create a shadow twice as long. An object six times as tall as the meter stick will create a shadow six times as long. Because there is a direct relationship between the height of objects and the length of their shadows, you can set up a proportion to figure out the height of an object based on the length of its shadow:

$$\frac{\text{height of meter stick}}{\text{length of meter stick shadow}} = \frac{\text{height of object}}{\text{length of object shadow}}$$

Now measure the length of the tree's shadow. Remember that shadow length changes throughout the day, so if more than a few minutes has passed since you measured the meter stick shadow, you will need to measure it again.

If the length of the meter stick shadow is 1.25 meters and the length of your tree's shadow is 4.25 meters, you would set up your proportion like this:

$$\frac{1.00\text{ meter}}{1.25\text{ meter}} = \frac{\text{height of tree}}{4.25\text{ meter}}$$

Multiply both sides of your equation by the length of object shadow to find the height of the tree:

$$4.25\text{ meter} \times \frac{1.00\text{ meter}}{1.25\text{ meter}} = \frac{\text{height of tree}}{4.25\text{ meter}} \times 4.25\text{ meter}$$

$$3.40\text{ meters} = \text{height of tree}$$

**Activity:** Use your own measurements in the proportion above to find the height of your tree. This process is called **indirect measurement**, because rather than using a tool to measure the height directly, you measured something else and used that measurement to calculate the height. What is the height of your tree? Be sure to include units in your answer.

______________________________

## 2. Measuring the width of a compact disk

Indirect measurement is also used to measure small quantities. It is difficult, for example, to get an accurate measurement of the width of one compact disk using a ruler. The CD is just too thin! However, if you had a stack of CD's, you could measure the height of the stack. Dividing this height by the number of CD's in the stack will tell you the width of one stack.

**Activity:** Locate a centimeter ruler and at least eight CD's. Calculate the width of one CD.

## 3. Using indirect measurement to solve problems

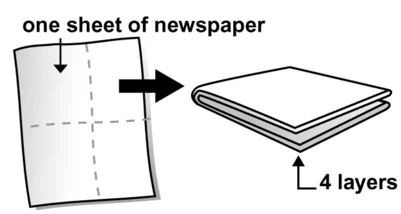
1. If you place one staple on an electronic balance, the balance still reads 0.0 grams. However, if you place 210 staples on the balance, it reads 6.80 grams. What is the mass of one staple?

2. A sculptor wants to create a statue. She goes to a quarry to buy a block of marble. She finds a chip of marble on the ground. The volume of the chip is 15.3 $cm^3$. The mass of the chip is 41.3 grams. The sculptor purchases a block of marble 30.0-by-40.0-by-100. cm. Use a proportion to find the mass of her block of marble.

3. The instructions on a bottle of eye drops say to place three drops in each eye, using the dropper. How could you find the volume of one of these drop? Write a procedure for finding the volume of a drop that includes using a glass of water, a 10.0-mL graduated cylinder, and the dropper.

4. A stack of 55 business cards is 1.85 cm tall. Use this information to determine the thickness of one business card.

5. A student wants to use indirect measurement to find the thickness of a sheet of newspaper. In a 50-centimeter tall recycling bin, she finds 50 sheets of newspaper. Each sheet in the bin is folded in fourths. Design a procedure for the student to use that would allow her to measure the thickness of one sheet of newspaper with little or no source of experimental error. The student has a meter stick and a calculator.



**Name:** ______________________________

# Skill Sheet 17-A Density

The density of a substance is a measure of how much mass is "packed" into a certain volume of the substance. Substances with a high density, like steel, have molecules that are packed together tightly. Substances with a low density, like cork, have fewer molecules packed into the same amount of space.

The density of a substance can be found by dividing its mass by its volume. As long as a substance is homogeneous, the size or shape of the sample of the substance doesn't matter. The density will always be the same. This means that a steel paper clip has the same density as a steel girder used to build a bridge.

## 1. Finding density

You can use the formula below to find the density of a substance.

$$Density = \frac{mass}{volume}$$

For example, you have a block of aluminum with a volume of 30.0 $cm^3$ and a mass of 81.0 grams. To find its density, divide the mass (81.0 grams) by the volume (30.0 $cm^3$).

$$Density = \frac{81.0 g}{30.0 cm^3}$$

The density of aluminum is 2.70 $g/cm^3$.

A note regarding units for density: Because one milliliter takes up the same amount of space as one cubic centimeter, density can be expressed in units of g/mL or $g/cm^3$. Liquid volumes are most commonly expressed in milliliters, while volumes of solids are usually expressed in cubic centimeters.

**Try these problems on your own:**

a. A solid rubber stopper has a mass of 33.0 grams and a volume of 30.0 $cm^3$. What is the density of rubber?

b. A chunk of paraffin (wax) has a mass of 50.4 grams and a volume of 57.9 $cm^3$. What is the density of paraffin?

c. A marble statue has a mass of 6200 grams and a volume of 2296 $cm^3$. What is the density of marble?

## 2. Using density to find mass

If you know the density of a substance and the volume of a sample, you can calculate the mass of the sample. To do this, rearrange the equation above to find mass:

$$Density = \frac{mass}{volume}$$

$$volume \times Density = \frac{mass}{volume} \times \frac{volume}{1}$$

$$volume \times Density = mass$$

Here's an example: The density of iron is 7.9 g/cm$^3$. If you have an iron horseshoe with a volume of 89 cm$^3$, what is the mass of the horseshoe?

To solve the problem, multiply the volume of the horseshoe by the density of iron.

$$89.0\,cm^3 \times 7.90\frac{g}{cm^3} = mass$$

The mass of the horseshoe is 703 grams.

**Try these problems on your own:**

a. The density of ice is 0.92 g/cm$^3$. An ice sculptor orders a one cubic meter block of ice. What is the mass of the block? Hint: 1 m$^3$ = 1,000,000 cm$^3$.

b. The density of platinum is 21.4 g/cm$^3$. A disk of pure platinum has a volume of 113 cm$^3$. What is the mass of the disk?

c. The density of seawater is 1.025 g/mL. What is the mass of 1.00 liter of seawater? (Hint: 1 liter = 1,000 mL)

## 3. Using density to find volume

If you know the density of a substance and the mass of a sample, you can find the volume of the sample. This time, you will rearrange the density equation to find volume.

$$volume \times Density = mass$$

$$\frac{1}{Density} \times Density \times volume = mass \times \frac{1}{Density}$$

$$volume = \frac{mass}{Density}$$

**Sample problem:** The density of lead is 11.3 g/cm$^3$. Find the volume of a 525-gram block of lead.

To solve this problem, divide the mass of the block by the density of lead.

$$volume = \frac{525g}{11.3\frac{g}{cm^3}}$$

The volume of the block is 46.5 cm$^3$.

**Try these problems on your own:**

a. The density of cork is 0.24 g/cm$^3$. What is the volume of a 240-gram piece of cork?

b. The density of gold is 19.3 g/cm$^3$. What is the volume of a 575-gram bar of pure gold?

c. The density of mercury is 13.6 g/mL. What is the volume of a 155-gram sample of mercury?

## 4. Using density to solve problems

Knowing the density of a substance can help you solve problems. Recycling centers, for example, use density to help sort and identify different types of plastics so that they can be properly recycled. The chart below shows common types of plastics, their recycling code, and density.

| Plastic name | Common uses | Recycling code | Density ($g/cm^3$) |
|---|---|---|---|
| PETE | 2-liter soda bottles | 1 | 1.38-1.39 |
| HDPE | milk cartons | 2 | 0.95-0.97 |
| PVC | plumbing pipe | 3 | 1.15-1.35 |
| LDPE | trash can liners | 4 | 0.92-0.94 |
| PP | yogurt containers | 5 | 0.90-0.91 |
| PS | cd “jewel cases” | 6 | 1.05-1.07 |

**Use the table on the previous page to solve the following problems:**

a. A recycling center has a 125,000 $cm^3$ box filled with one type of plastic. When empty, the box had a mass of 755 grams. The full box has a mass of 120.8 kg (120,800 g). What is the density of the plastic? What type of plastic is in the box?

b. A truckload of 2-liter soda bottles was finely shredded at a recycling center. The plastic shreds were placed into 55-liter drums. What is the mass of the plastic shreds inside one of the drums? Hint: 55 liters = 55,000 milliliters = 55,000 $cm^3$.

c. A recycling center has 100 kilograms (100,000 grams) of shredded plastic yogurt containers. How many 10-liter (10,000 mL) containers do they need to hold all of this plastic?

d. A solid will float in a liquid if it is less dense than the liquid, and sink if it is more dense than the liquid. If the density of seawater is 1.025 g/mL, which types of plastics would definitely float in seawater?

**Name:** ______________________________

## Skill Sheet 17-B Ratios and Proportions

Speed, the density of a solid, and pressure are all measurements that are given as ratios. When you set two ratios equal to each other we call this equation a proportion. In this skill sheet, you will investigate the techniques used to analyze and manipulate ratio- and proportion-based formulas and examine a few specific examples of how these concepts are applied in science.

### 1. Understanding ratios and proportions

What is a *ratio*? Ratios are expressions of relationships or comparisons. In general, ratios express the relationship:

$$\frac{\text{amount or magnitude of a sample}}{\text{total amount or magnitude of system containing the sample}}$$

For example, suppose you have a jar filled with 100 marbles. This is the total number of marbles in the system. You are asked to report the number of red marbles in the jar. This is the amount of a specific sample of the marbles. After counting, you find that 25 of the 100 marbles are red. As a relationship, you could say that you had 25 marbles compared to the total 100 marbles in the jar. You can express this relationship—25 red marbles compared to 100 total marbles—as a fraction:

$$\frac{\text{25 red marbles}}{\text{100 total marbles}}$$

You can use this ratio to analyze other systems of marbles.

Let's say this particular brand of marbles come in jars of 100 or 300. Because you know how many marbles out of 100 are red, you can predict how many marbles out of 300 are red by setting up a *proportion*.

The advantage of setting up a proportion is that you can get a good estimate of the number of something without having to spend time counting each marble. The proportion for the marbles is set up for you below:

$$\frac{\text{25 red marbles}}{\text{100 total marbles}} = \frac{\text{? red marbles}}{\text{300 total marbles}}$$

Now that you have the proportion, you need to solve it. To solve a proportion, you use a technique called *cross multiplication*.

## 2. Cross Multiplication

Cross multiplication is a mathematical technique to solve proportions, also known as *equivalent fractions*. Our sample problem is an example of equivalent fractions. Each fraction represents a system. One system has 100 marbles and the other has 300 marbles. However, each of these systems share the same relationship—that 25 marbles in every 100 marbles are red.

When using cross multiplication, you multiply across the equal sign between the fractions. You first multiply the numerator of the first fraction by the denominator of the second fraction:

$$\frac{\text{25 red marbles}}{\text{100 total marbles}} = \frac{\text{? red marbles}}{\text{300 total marbles}}$$

You then multiply the denominator of the first fraction by the numerator of the second fraction:

$$\frac{\text{25 red marbles}}{\text{100 total marbles}} = \frac{\text{? red marbles}}{\text{300 total marbles}}$$

This gives you a new formula:

$$(\text{25 red marbles}) \times (\text{300 total marbles}) = (\text{100 total marbles}) \times (\text{? red marbles})$$

The next step in cross multiplication is to solve for the number of red marbles in the jar containing 300 marbles.

For this problem, you divide each side of the equation by 100 total marbles. On the right hand side of the equation, you have 100 total marbles divided by 100 total marbles. These values cancel out leaving "**? red marbles**."

$$\frac{(\text{25 red marbles}) \times (\text{300 total marbles})}{\text{100 total marbles}} = \frac{(\text{100 total marbles}) \times (\text{? red marbles})}{\text{100 total marbles}}$$

$$\text{75 red marbles} = \text{? red marbles}$$

Solving the left-hand side of the equation results in a value of 75 red marbles. Based on the relationship for the smaller jar of marbles, this value is a good prediction of how many red marbles you would find in the jar of 300 marbles.

## 3. Examples of ratios and proportions

**Example 1: Density**

Density is a relationship between the mass of a substance and the amount of space it occupies:

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

For a single type of substance, the density relationship is constant. Therefore, you can use this relationship, or ratio, to predict the mass or volume for a sample of the substance using equivalent fractions:

$$\text{Density}_1 = \text{Density}_2$$

$$\frac{M_1}{V_1} = \frac{M_2}{V_2}$$

where $M_1$ and $V_1$ are the mass and volume of a *sample* of a substance and $M_2$ and $V_2$ are the mass and volume of the substance. Here's an example problem:

You have a block of aluminum with a mass of 369 g and a volume of 136.4 $\text{cm}^3$. If the block is cut in half, what is the mass of the resulting sample?

You have reduced the volume of the block by half, so the new volume is 68.2 $\text{m}^3$. The density of the sample and the relationship between the mass and volume is constant, so you can set up a set of equivalent fractions:

$$\frac{M_1}{V_1} = \frac{M_2}{V_2}$$

$$\frac{369\text{ g}}{136.4\text{ cm}^3} = \frac{M_2}{68.2\text{ cm}^3}$$

$$(369\text{ g}) \times (68.2\text{ cm}^3) = (136.4\text{ cm}^3) \times (M_2)$$

$$\frac{(369\text{ g}) \times (68.2\text{ cm}^3)}{(136.4\text{ cm}^3)} = \frac{(136.4\text{ cm}^3) \times (M_2)}{(136.4\text{ cm}^3)}$$

$$185\text{ g} = M_2$$

The new block will have a mass of 185 g. If you calculate the densities of the two blocks, the original and the new, they both have the same value 2.7 $\text{g/cm}^3$.

**Example 2: Pressure**

Pressure is defined as a force acting over a given area. Mathematically, you may express pressure with the formula:

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

Here's an example problem:

Consider a machine designed to produce 4 N/cm$^2$ of pressure during a manufacturing process. How much area would be required deliver a force of 36 N?

Knowing that the relationship of force to area in this case is constant, you can use proportions and ratios to evaluate the area over which the machine needs to apply this new force. Setting up the equivalent fractions:

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$\frac{4\text{ N}}{1\text{ cm}^2} = \frac{36\text{ N}}{A_2}$$

$$(4\text{ N}) \times (A_2) = (1\text{ cm}^2) \times (36\text{ N})$$

$$\frac{(4\text{ N}) \times (A_2)}{(4\text{ N})} = \frac{(1\text{ cm}^2) \times (36\text{ N})}{(4\text{ N})}$$

$$A_2 = 9\text{ cm}^2$$

## 4. Working with ratios and proportions

1. A barrel contains 250 apples. 100 of the apples are red, and 150 of the apples are green. Express the number of red and green apples to the total number in the barrel as two ratios.

2. The number of jazz and blues CD's to the total number of CD's at a music store can be expressed with the ratio $^1/_4$. If there are 1,000 total CD's in the store, how many belong in the jazz and blues category?

3. The owner of the music store in question (2) sees that jazz and blues CD's are selling particularly well. He changes the number of the jazz and blues CD's that he stocks. He now carries 500 jazz and blues CD's out of his total stock of 1,000 CD's. What ratio expresses this new amount of jazz and blues CD's to total CD's in the store?

4. A sample of material has a mass of 15 g and occupies a space of 45 $cm^3$. If material is added to the sample so that the new mass equals 60 g, how much space will the sample now occupy?

---

5. A woman needs to ship a 5 $m^2$ glass block to an artist in California. She knows that a 2 $m^2$ glass block has a mass of 6 kg. To give her customer a prediction of the shipping cost, she needs to know the mass of the 5 $m^2$ block. What mass value would she tell the post office to calculate the cost of shipping?

---

6. The concept of power expresses the rate at which work is performed. It is calculated using the equation:

$$\text{Power} = \frac{\text{work}}{\text{time}}$$

A machine is capable of producing 250.0 joules of work in 45.00 seconds. If the machine operates for 600.0 seconds, how much work will be performed?

---

7. A baker has to bring cheesecakes to a big Hollywood party. Each cheesecake will serve 12 guests. The total number of guests expected at the party is 720.

   a. How many cheesecakes will the baker need to prepare for the party?

---

   b. The host of the party decides that he wants $^1/_4$ of the cheesecakes to be blueberry, $^1/_4$ of the $^1/_4$ cheesecakes to be chocolate, and $^1/_2$ of the cheesecakes to be plain. How many blueberry, chocolate, and plain cheesecakes does the baker need to prepare?

---

   c. While talking to potential guests, the party host finds that about $^1/_3$ of them might prefer carrot cake to the cheesecake he was planning to offer. He, therefore, instructs the baker to prepare carrot cakes in addition to the cheesecakes. If the baker plans for $^1/_3$ of the guests having the option of carrot cake, how many carrot cakes does he need to bake (each carrot cake also serves 12 people)?

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**Name:** ______________________________

# Skill Sheet 17-C Buoyancy

Why do some objects float in water, while other objects sink? Why do some objects (like helium balloons) rise into the air when released from your hand, while other objects drop to the ground? To answer these questions, you need to understand buoyancy. In this skill sheet, you will examine the concept of buoyant forces. Next, you will practice calculating the buoyant force acting on an object placed in a fluid. You will use your calculations to figure out whether the object floats or sinks in that particular fluid.

## 1. Buoyant force

Physical scientists use the word *fluid* to describe any matter that can flow. The matter could be a liquid, like water, or a gas, like air. When an object is placed in a fluid (liquid or gas), the fluid exerts an upward force upon the object. This force is called a *buoyant force*.

At the same time, there is an attractive force between the object and Earth, which we call the force of gravity. It acts as a downward force.

To determine whether an object will rise, sink, or float, compare the size of the buoyant force to the size of the gravitational force (the weight of an object). If the buoyant force and the gravitational force are equal, the object will float. If the buoyant force is greater than the gravitational force, the object will rise in the fluid. If the gravitational force is greater it will sink.

**Questions to try:** For each of the following, compare the buoyant force to the gravitational force acting on the object. Explain your answers.

1. A rock is dropped into a pond. (The object is the rock. The fluid is the pond water.)

______________________________

2. A child releases the string attached to a helium-filled balloon. (The object is the balloon. The fluid is air.)

______________________________

3. An inflated beach ball is tossed into a swimming pool. The object is the beach ball. The fluid is the pool water.)

______________________________

## 2. Calculations with buoyant force

Here is an example that illustrates how to determine whether an object will sink or float in a fluid when you have been given values for the buoyant and gravitational forces.

**Example:**

A 13-newton object is placed in a container of fluid. If the fluid exerts a 60-newton buoyant (upward) force on the object, will the object float or sink?

**Answer:**

In this case, the upward buoyant force (60 N) is greater than the weight of the object (13 N). Therefore, the object will float.

**Now try these problems on your own:**

1. A 4.5-newton object is placed in a tank of water. If the water exerts a force of 4.3 newtons on the object, will the object sink or float?

2. The same object is placed in a tank of glycerin. If the glycerin exerts a force of 5.2 newtons on the object, will the object sink or float?

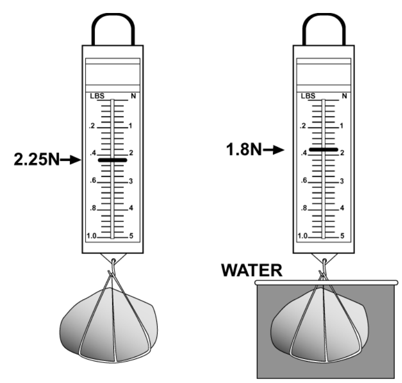
3. Would this same object be more likely to float in molasses or in vegetable oil? Explain why you think this is true.

## 3. Calculating buoyant force acting on an object that sinks

In the problems above, you were given the size of each force. How were those forces measured?

It's easy to find the gravitational force. You simply use a spring scale to measure the object's weight.

Finding the buoyant force is a little more complicated. Take a look at this example:




The rock weighs 2.25 newtons when suspended in air. In water, it appears to weigh only 1.8 newtons. Why? The rock didn't shrink! The water is exerting a force on the rock. You can calculate the buoyant force by finding the difference between the rock's weight in air and its apparent weight in water.

$$2.25\ \text{N} - 1.8\ \text{N} = 0.45\ \text{N}$$

The water exerts a buoyant force of 0.45 newtons on the rock.

**Try these problems on your own:**

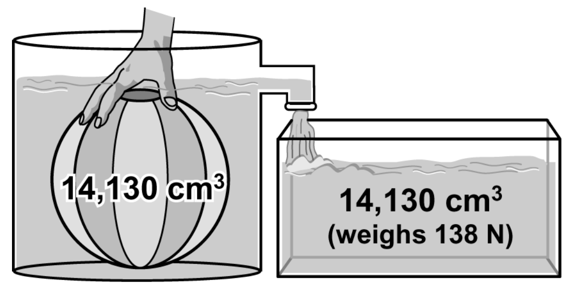
1. You suspend a brass ring from a spring scale. Its weight is 0.83 N. Next, you immerse the rock in a container of light corn syrup. The ring appears to weigh 0.71 N. What is the buoyant force acting on the ring?

2. You wash the brass ring and then suspend it in a container of vegetable oil. The ring appears to weigh 0.73 N. What is the buoyant force acting on the ring?

3. Which has greater buoyant force, the light corn syrup or the vegetable oil? Why do you think this is so?

## 4. Calculating buoyant force acting on an object that floats

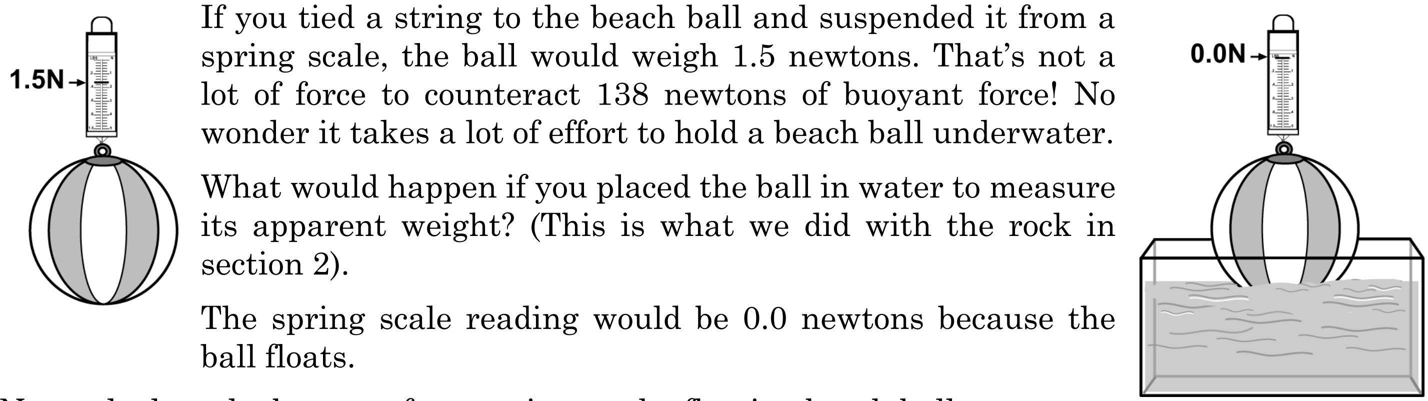
Have you ever tried to hold a beach ball underwater? It takes a lot of effort because the buoyant force is much larger than the gravitational force acting on the ball.




We can use Archimedes principle to calculate the buoyant force acting on the beach ball. **Archimedes principle** states**:**

The buoyant force acting on an object in a fluid is equal to the weight of the fluid displaced by the object.

The beach ball's volume is 14,130 $cm^3$. If you pushed it underwater, the ball displaces 14,130 $cm^3$ of water. Archimedes principle tells us that the buoyant force equals the weight of that water. The weight of 14,130 $cm^3$ of water is 138 N. The buoyant force acting on the ball is 138 N.




If you tied a string to the beach ball and suspended it from a spring scale, the ball would weigh 1.5 newtons. That's not a lot of force to counteract 138 newtons of buoyant force! No wonder it takes a lot of effort to hold a beach ball underwater.

What would happen if you placed the ball in water to measure its apparent weight? (This is what we did with the rock in section 2).

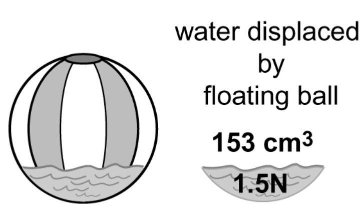
The spring scale reading would be 0.0 newtons because the ball floats.

Now calculate the buoyant force acting on the floating beach ball:

gravitational force acting on ball - apparent weight of ball in water = buoyant force acting on ball:

$$1.5\text{ N} - 0.0\text{ N} = 1.5\text{ N}$$

The buoyant force acting upward on the floating beach ball is equal to the gravitational force pulling the ball downward.




The *floating* ball doesn't displace 14,130 $cm^3$ of water. It displaces only 153 $cm^3$ of water. 153 $cm^3$ of water weighs 1.5 newtons. The ball displaces an amount of water equal to its own weight.

## 5. Solving buoyancy problems

Use what you have learned to solve the following problems. The first one is done for you.

1. A 5-$cm^3$ block of lead weighs 0.55 N. The lead is carefully submerged (held under the surface) in a tank of mercury. One $cm^3$ of mercury weighs 0.13 N.
   a. What is the weight of the mercury displaced by the block of lead?
   b. If the block is released, will the block of lead rise, sink, or float in the mercury?
   c. What weight of mercury is displaced by the lead block after it is released?
   d. What volume of mercury is displaced by the lead block after it is released?

**Answers to question #1:**

(a) The lead will displace 5 $cm^3$ of mercury. $5 \times 0.13$ N = 0.65 N.

(b) The buoyant force, 0.65 N, is greater than the weight of the lead, 0.55 N, so the lead floats.

(c) The weight of the mercury displaced by the floating block of lead equals the weight of the block, 0.55 N.

(d) Since the block floats when the weight of the mercury displaced equals the weight of the lead, then the volume displaced is:

$$\frac{1.0\text{cm}^3}{0.13\text{ N}} = \frac{\text{volume displaced in cm}^3}{0.55\text{ N}}$$

$$\text{volume displaced} = 4.2\text{cm}^3$$

2. A 10 $cm^3$ block of paraffin (a type of wax) weighs 0. 085 N. It is carefully submerged in a container of gasoline. One $cm^3$ of gasoline weighs 0.0069 N.
a. What is the weight of the gasoline displaced by the paraffin?

---

b. Will the block of paraffin sink or float in the gasoline?

---

3. A 30 $cm^3$ chunk of platinum weighs 6.3 N. It is carefully submerged in a tub of molasses. One $cm^3$ of molasses weighs 0.013 N.
a. What is the weight of the molasses displaced by the platinum?

---

b. Will the platinum sink or float in the molasses?

---

4. A 15 $cm^3$ block of gold weighs 2.8 N. It is carefully submerged in a tank of mercury. One $cm^3$ of mercury weighs 0.13 N.
a. What is the weight of the mercury displaced by the gold?

---

b. Will the gold sink or float in the mercury?

---

5. Compare the densities of each pair of materials in the questions (1 - 4) above.

| material | density (g/ $cm^3$) |
|---|---|
| gasoline | 0.7 |
| gold | 19.3 |
| lead | 11.3 |
| mercury | 13.6 |
| molasses | 1.37 |
| paraffin | 0.87 |
| platinum | 21.4 |

Does an object’s density have anything to do with whether or not it will float in a particular liquid? Give at least three examples to support your answer. Write your answer as a paragraph on a separate piece of paper.

Name:

# Skill Sheet 17-D Gases and Pressure

Have you ever pumped up a bicycle tire? What is happening inside of the tire? As you pump more air into the tire, more and more particles of air are pushed into the tire, increasing the pressure inside. On a microscopic level, each particle of air collides with the inside walls of the tire, exerting a force which pushes the inner surface of the tire outward. As you pump more air into the tire, there are more particles that can exert forces on the inside walls of the tire. The forces of all of the particles of air inside the tire add together to create pressure. This skill sheet will help you practice solving problems that involve changes in the pressure of a gas due to changes in volume or temperature.

## 1. Boyle's law: pressure and volume

The relationship between the volume of a gas and the pressure of a gas, at a constant temperature, is known as Boyle's law. The equation for Boyle's law is:

***Boyle's law***

Initial pressure → $P_1$; Initial volume → $V_1$; New pressure → $P_2$; New volume → $V_2$

$$P_1 V_1 = P_2 V_2$$

Here's how you solve a problem using this relationship:

A kit used to fix flat tires consists of an aerosol can containing compressed air, and a patch to seal the hole in the tire. Suppose 10.0 liters of air at atmospheric pressure (101.3 kilopascals, or kPa) is compressed into a 1.0 liter aerosol can. What is the pressure of the compressed air in the can?

1. Identify what you know and what you are trying to find out from the information given.

   $\mathbf{P_1}$ = 101.3 kPa
   $\mathbf{V_1}$ = 10.0 L
   $\mathbf{P_2}$ = unknown
   $\mathbf{V_2}$ = 1.0 L

2. Rearrange the variables in the equation to solve for the unknown variable.

Divide each side by $\mathbf{V_2}$ to isolate $\mathbf{P_2}$ on one side of the equation. The final equation is:

$$P_2 = \frac{P_1 V_1}{V_2}$$

3. Plug in the values and solve the problem.

$$P_2 = \frac{101.3\ \text{kPa} \times 10.0\ \text{L}}{1.0\ \text{L}} = 1013\ \text{kPa}$$

The pressure inside of the aerosol can is 1,013 kPa.

## 2. Charles' law: pressure and temperature

The French scientist Jacques Charles was a pioneer in hot-air ballooning. He investigated how changing the temperature of a fixed amount of gas at constant pressure affected its volume. The equation for this relationship is:

***Charles' law***

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Initial volume → $V_1$; Initial temperature → $T_1$; $V_2$ ← Final volume; $T_2$ ← Final temperature

Charles' law shows a direct relationship between the volume of a gas and the temperature of a gas when the temperature is given in the **Kelvin scale**. Zero on the Kelvin scale is the coldest possible temperature, also known as absolute zero. Absolute zero is equal to -273 °C which is 273 °C below the freezing point of water. Why do you think this scale is used to solve these problems?

Converting from degrees Celsius to Kelvin is very easy. You *add* 273 to the Celsius temperature. To convert from Kelvins to degrees Celsius, you *subtract* 273 from the Kelvin temperature.

To solve problems with Charles' law, you can follow the same problem-solving steps you learned for Boyle's law, except you use the equation for Charles' law. You also need to convert degrees Celsius to Kelvin. To practice both equations, do the problems below.

## 3. Practice problems with Boyle's and Charles' laws

1. A truck tire holds 25.0 L of air at 25.0 °C. If the temperature drops to 0.00 °C, and the pressure remains constant, what will be the new volume of the tire?
   (HINT: remember to convert degrees Celsius to Kelvins!)

---

2. You pump 25.0 L of air at atmospheric pressure (101.3 kPa) into a soccer ball that has a volume of 4.50 L. What is the pressure inside of the soccer ball if the temperature does not change?

---

3. Hyperbaric oxygen chambers (HBO) are used to treat divers with decompression sickness. Research has shown that HBO can also aid in the healing of broken bones and muscle injuries. As pressure increases inside of the HBO, more oxygen is forced into the bloodstream of the patient inside of the chamber. To work properly, the pressure inside of the chamber should be three times greater than atmospheric pressure (101.3 kPa). What volume of oxygen, held at atmospheric pressure will need to be pumped into a 190 L HBO chamber to make the pressure inside three times greater than atmospheric pressure?

---

4. A balloon holds 20.0 L of helium at 10 °C. If the temperature doubles, and the pressure does not change, what will be the new volume of the balloon?

5. A SCUBA tank holds 12.5 L of oxygen at 1013 kPa. If the oxygen that was pumped into the SCUBA tank was held at a pressure of 202.6 kPa, what was the original volume of gas that was pumped into the SCUBA tank?

**Use the space below to show your calculations for the problems:**

Name: ____________________

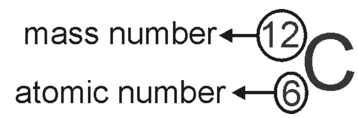
# Skill Sheet 18-A Atoms, Isotopes, and Ions

You have learned that atoms contain three smaller particles called protons (positive charge), neutrons (no charge) and electrons (negative charge). You have also learned that the number of protons determines the type of atom. In this skill sheet, you will learn about atoms that have the same number of protons, but different numbers of neutrons (isotopes) and different numbers of electrons (ions).

## 1. What are isotopes?

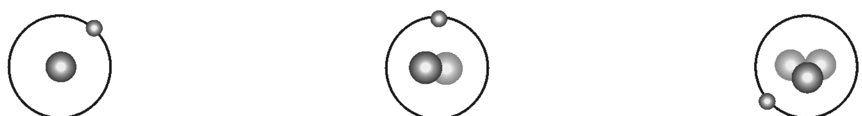
In addition to the atomic number, every atom can also be described by its **mass number**. The mass number is equal to the number of protons and neutrons in the nucleus of an atom. Recall that atoms of the same element have the same number of protons. Atoms of the same element *can* have different numbers of neutrons. These different forms of the same element are called **isotopes**.

Sometimes the mass number for an element is included in its symbol. When the symbol is written in this way, we call it **isotope notation**. The isotope notation for carbon-12 is shown to the right. You can determine the number of neutrons by subtracting the atomic number (bottom) from the mass number (top).




How many neutrons does an atom of carbon-12 have? To find out, simply take the mass number and subtract from it, the atomic number: **12 - 6 = 6**.

Hydrogen has three isotopes as shown below.



$^{1}_{1}H$ Protium

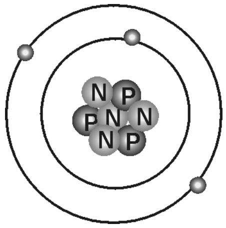
$^{2}_{1}H$ Deuterium

$^{3}_{1}H$ Tritium

1. How many neutrons does protium have? How about deuterium and tritium?

____________________

2. Use the diagram of an atom to answer the questions:




a. What is the atomic number of the element?

____________________

b. What is the name of the element?

____________________

c. What is the mass number of the element?

____________________

d. Write the isotope notation for this isotope.

____________________

## 2. What is the atomic mass?

If you look at a periodic table, you will notice that the atomic number increases by one whole number at a time. This is because you add one proton at a time for each element. The **atomic mass** (see diagram below) however, increases by amounts greater than one. This difference is due to the neutrons in the nucleus. The value of the atomic mass reflects the abundance of the stable isotopes for an element that exist in the universe.


Since silver has an atomic mass of 107.87, this means that most of the stable isotopes that exist have a mass number of 108. In other words, the most common silver isotope is "silver-108." To figure out the most common isotope for an element, round the atomic mass to the nearest whole number.

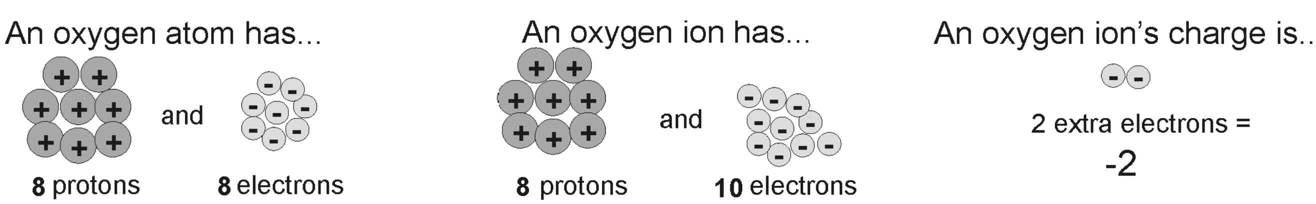
1. Look up bromine on the periodic table. What is the most common isotope of bromine?

2. Look up potassium on the periodic table. How many neutrons does the most common isotope of potassium have?

## 3. What are ions?

Many atoms tend to gain or lose some of their electrons. When atoms gain or lose electrons, they are no longer neutral, but have an electrical charge that is either positive or negative. Atoms that have a positive or negative charge are called **ions**.

You can determine the electric charge of an ion by simply comparing the number of protons and electrons. If there are more protons than electrons, then the ion has a *positive* charge that is equal to the number of extra protons. If there are more electrons than protons, then the ion has a *negative* charge that is equal to the number of extra electrons. For example:




1. A sodium ion has 11 protons and 10 electrons. What is its charge?

2. A magnesium ion has 12 protons and 10 electrons. What is its charge?

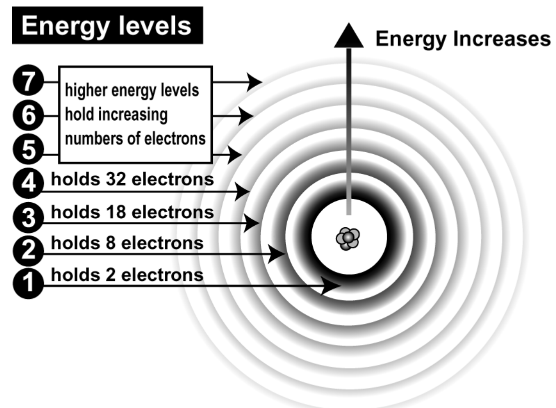
Name: ______________________________

# Skill Sheet 18-B Electrons and the Periodic Table

What do electrons have to do with the periodic table? In this skill sheet, you will learn how electrons are organized in the energy levels that orbit the nucleus of an atom. You will also discover the relationship between electrons and the organization of the periodic table.

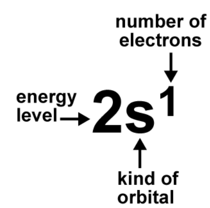
## 1. How do you describe the location of an electron?

As you have learned, electrons "live" in one of the seven **energy levels** surrounding the nucleus of the atom. Generally speaking, the farther away from the nucleus the energy level, the greater the amount of energy required for an electron to occupy that level. Electrons tend to fill in the first energy level first, the second energy level second, and so on, because they fill the levels from lowest to highest energy, that is, from first to outermost.




Energy levels are divided into smaller regions called **orbitals**. Each orbital designates a specific region of the energy level where an electron exists. The different orbitals are designated by the letters **s**, **p**, **d**, and **f**.

Electrons fill the energy levels and orbitals in a certain order. The position that has the lowest energy is filled first. The position that has the lowest energy is in the first energy level (the level closest to the nucleus), in the **s** orbital. This electron's position is represented by writing: $\mathbf{1s^1}$.




The order in which electrons fill *all* seven energy levels (1-7) and *all* electron orbitals (**s**, **p**, **d**, and **f**) is shown below. This order (going from left to right) is called an **electron configuration**.

**Electron configuration for ununoctium**

| Lowest energy | → | → | → | → | → | Highest energy |
|---|---|---|---|---|---|---|

$\mathbf{1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ \ 4s^2\ 3d^{10}\ 4p^6\ \ 5s^2\ 4d^{10}\ 5p^6\ \ 6s^2\ 4f^{14}\ 5d^{10}\ 6p^6 7s^2\ 5f^{14}\ 6d^{10}\ 7p^6}$

Each element on the periodic table has a unique electron configuration, based on its atomic number This number tells you the number of electrons in a neutral atom of the element. For example, hydrogen's electron configuration is $1s^1$ and carbon's electron configuration is $1s^2 2s^2 2p^2$. The electron configuration above (which includes all the energy levels and orbitals on the periodic table) is for ununoctium (Uuo), the very last element on the periodic table.

In the fourth, fifth, sixth, and seventh energy levels, you will notice orbitals with numbers from a lower energy level. For example, the 4s and 4p orbitals and the 3d orbital are all in the fourth energy level. This is because the energy level of the 3d electrons overlaps with the energy levels for electrons in the fourth energy level. Also, the 4s orbital is filled before the 3d orbital. This is because the 4s orbital has a lower energy than the 3d orbital. To complicate matters, electrons fill the **d** and **f** orbitals in irregular patterns.

## 2. Writing electron configurations

Can you write the electron configuration for gallium? Since this may be your first time, we'll do this one together by following the steps below.

1. Locate the element on the periodic table.

   Look at a periodic table and locate gallium. Its symbol is Ga. Use the atomic number to determine how many electrons a neutral atom of gallium has.

   Gallium has 31 electrons.

2. Fill orbitals in the proper sequence with electrons.

   Use table on the previous page as a guide for the order of filling each energy level and orbital. Keep filling orbitals until you have placed all the electrons of the element. The electron configuration for gallium is:

   $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^1$

3. Check to make sure that the total number of electrons in the configuration (the superscripts) is equal to the atomic number.

   $2 + 2 + 6 + 2 + 6 + 2 + 10 + 1 = 31$

   Congratulations! You have successfully written an electron configuration. You'll have plenty more practice as you work through this skill sheet.

## 3. An easier way to write electron configurations

You can save yourself a lot of time (and space in your notebook) if you use an abbreviated form of writing electron configurations using noble gases. Here's an example of how to do this with the electron configuration for gallium:

Gallium is in the fourth period. You can substitute the electrons that are in the third period of the periodic table with the symbol for the noble gas that is in that period. What is the noble gas in the third period? Remember that elements in the last column of the periodic table (group 18) are the noble gases.

Argon is the noble gas in the third period. To write the abbreviated electron configuration for gallium, substitute the symbol for argon, in brackets, for the electron configuration of the first three periods. Next, write the rest of gallium's electron configuration.

Electron configuration for gallium:

$$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^1$$

$$[1s^2 2s^2 2p^6 3s^2 3p^6] = \text{argon} + 4s^2 3d^{10} 4p^1$$

The abbreviated electron configuration for gallium is:

$$[Ar]4s^2 3d^{10} 4p^1$$

Writing abbreviated electron configurations is a convenient way to see how many electrons are in the outermost s and p orbitals of an atom. These are the electrons that are involved in forming chemical bonds. How many electrons does gallium have in its outermost s and p orbitals? *Answer: 3 electrons*

## 4. Writing electron configurations for some of the elements

Write abbreviated electron configurations for the following elements. Use a periodic table to locate the elements and determine the number of electrons. Finally, fill in the last column of the table. For elements in the lanthanide or actinide series, write “lanthanide” or “actinide” instead of a group number.

| Element | Electron configuration (abbreviated form) | To which group does this element belong? |
|---|---|---|
| **K** | | |
| **Rb** | | |
| **Mg** | | |
| **Ba** | | |
| **Tl** | | |
| **Ga** | | |
| **Pb** | | |
| **Sn** | | |
| **Mo** | | |
| **N** | | |
| **Sb** | | |
| **Pt** | | |
| **Se** | | |
| **Po** | | |
| **Br** | | |
| **Gd** | | |
| **Cl** | | |
| **Kr** | | |
| **U** | | |
| **Rn** | | |

## 5. Identifying patterns in the arrangement of elements on the periodic table

Look at the table you have just filled in. Do you see any patterns in the electron configurations and group numbers? Use the patterns you see in the electron configurations to answer the following questions.

1. In the main group elements (the tall columns on the periodic table), what is the relationship between group number and number of electrons in the outermost **s** and **p** orbitals?

2. Which elements in the table you completed belong to the transition metals? What do their electron configurations have in common?

3. Which elements in the table you completed belong to the lanthanide and actinide series (the two separate rows at the bottom)? What do their electron configurations have in common?

4. Which elements have a completely full outermost energy level? Where are they located?

## 6. Valence electrons

In the main group elements, the electrons in the **s** and **p** orbitals of the outermost energy level are called **valence electrons**. These electrons are involved in forming chemical bonds.

1. How many electrons can the **s** orbital of a given energy level hold?

2. How many electrons can the **p** orbital of a given energy level hold?

3. If valence electrons include the electrons in the **s** and **p** orbitals for an energy level, what is the maximum number of valence electrons an atom can have?

4. How is the placement of an element on the periodic table related to the number of valence electrons the element has?