SUPERCHARGED SCIENCE

Unit 20: Earth Science

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Appropriate for Grades:
Grades K-8 (see notes on each lesson)
Duration: 5-25 hours, depending on how many activities you do!

You are about to become a real meteorologist and geologist as you explore our dynamic planet. We'll first study the systems of the atmosphere and weather as you get to build a homemade weather station, complete with cloud tracker and hair hygrometer for measuring the Earth's atmosphere. You also get to learn about convention currents, liquid crystals, air pressure, and how sunlight, water, and wind can be used as sources of energy.

You'll also learn about the world of rocks, crystals, gems, fossils, and minerals by moving beyond just looking at pretty stones and really being able to identify, test, and classify samples and specimens you come across using techniques that real field experts use. While most people might think of a rock as being fun to climb or toss into a pond, you will now be able to see the special meaning behind the naturally occurring material that is made out of minerals by understanding how the minerals are joined together, what their crystalline structure is like, and much more.

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Key Vocabulary

Condensation – when a gas forms into a liquid while suspended in the air, usually on some surface such as a beverage glass.

Crystal – a group of rigid molecules arranged in a regular, repeating pattern. They are the basic units for mineral structures, and are classified according to their chemical makeup and physical properties.

Dew point – the temperature that moist air will saturate and condense into fog.

Electromagnetic spectrum – how the light emitted in the universe is categorized according to energy and wavelength. Includes radio waves, microwaves, ultraviolet, infrared, visible, x-rays, and gamma radiation.

Foliation –the process and final appearance of banded minerals within a larger rock feature, describing the flattening and lining up of mineral grains through heat and pressure in rock metamorphosis.

Geode - a deposit of mineral material that has formed crystals within a pocket.

Meteorology – the field of study investigating the weather and conditions of earth's atmosphere on a local, regional, and continental scale, usually over a shorter period of time.

Mineral - an inorg*anic,* crystalline, chemical substance that occurs naturally.

Nephology – a type of meteorology that deals with the study of clouds in the Earth's atmosphere

Radiation – energy given off by the sun, in the form of radio waves, microwaves, X-rays, and visible light, for example.

Rock – a compound made of two or more minerals, formed from different physical and chemical processes in the Earth's crust, and often from other rocks themselves.

Unit Description

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Objectives

Lesson 1: Atmosphere

You are about to become a real meteorologist and geologist as you explore our dynamic planet.

Here are the key concepts we'll be working with in this lesson:

- Weather can be observed, measured and described using scientific instruments.
- How to use simple tools (e.g., thermometer, wind vane) to measure weather conditions and record changes from day to day and over the seasons.
- The weather changes from day to day, but trends in temperature or of rain (or snow) tend to be predictable during a season.
- The sun warms the land, air, and water.
- Energy from the sun reaches the Earth through radiation.
- The color of a material will affect how much energy is absorbed and reflected by the object. Dark objects absorb more energy than lighter objects; lighter objects reflect more energy than darker objects.
- Water can be purified through coagulation, sedimentation, and filtration, or by distilling.
- Sub-cooling is when substances are cooled below their freezing point while still in a liquid state. In order to turn into a solid, the substance must heat up to its freezing temperature first before turning into a solid.
- Higher pressure always pushes.
- Air isn't invisible or a vacuum. It takes space, and we can record pressure, temperature, and volume measurements for air.
- Atmospheric pressure is 14.7 psi, or 1 atm.
- For air, when there's a decrease in volume, both temperature and pressure increases. When volume increases, temperature and volume decrease.

Objectives

Lesson 2: Geology

You'll learn about the world of rocks, crystals, gems, fossils, and minerals by moving beyond just looking at pretty stones and really being able to identify, test, and classify samples and specimens you come across using techniques that real field experts use. While most people might think of a rock as being fun to climb or toss into a pond, you will now be able to see the special meaning behind the naturally occurring material that is made out of minerals by understanding how the minerals are joined together, what their crystalline structure is like, and much more.

The main ideas in this lesson are:

- Minerals are the building blocks of rocks.
- Rocks are usually composed of two or more minerals (once in awhile, rocks can be made from just one, but usually it's two or more).
- Minerals are naturally occurring nonliving solids made from a single kind of material.
- Minerals have a regular internal arrangement of atoms and molecules (called crystals).
- Each mineral has its own unique combination of different chemical elements.
- When atoms and molecules combine to make a mineral, they form a type of crystal.
- Each mineral has a unique set of properties and can be identified using a series of standardized tests.

Textbook Reading

Lesson 1: Atmosphere

Can you feel air the top of your head? What's up there? How heavy is it?

What you are feeling is 50 miles of air pushing down on your brain. The atmosphere is what we live in everyday, and it's a giant sea of air, and it extends about 50 miles up until you get into outer space.

As you go up, the pressure decreases because there's less air pushing down on top of you. This air pressure not only pushes down, it also pushes up, around, to the left, right – it's the same air pressure everywhere: in shower, under bed, up your left nostril! It's the same 14.7 psi (pounds per square inch) of air pressure at sea level.

Of course, if you live on top of Mount Everest, the pressure will be a little less.

Have you ever seen the space shuttle launch? You'll notice that the fiery stream of rocket thrust expands as it climbs into through the atmosphere, because there's less pressure pushing it into the shape it was near the ground.

We can do things to change a little pocket of pressure, and when we change the air pressure in one spot, now there's a *difference* in air pressure, and this causes winds, storms, hurricanes, airplanes to fly, balloons to inflate, and the cool experiments we're going to do together in this lesson!

So how do we change air pressure? By heating or cooling, by blowing with a fan, and many other ways.

Imagine you are blowing up a balloon. Where is the higher pressure? Is it inside or outside the balloon?

Inside! The higher pressure on the inside pushes the balloon out to hold its shape. When you inflate your tires, you force more air into the tire and the pressure goes up. You can even read the increase in pressure on a tire gauge.

So this brings us to our key concept:

Higher pressure always pushes.

This is *the* fundamental concept that scientists use when designing their rockets, airplane wings, jet engines, and air balloons.

Let's test this idea out. Your job is to figure out where the difference in pressure is in these next couple of experiments. Are you ready?

Grab a sheet of paper – just a regular old sheet of paper. (It can be written on or blank – doesn't matter. Have your grown up do this for you if you need to.)

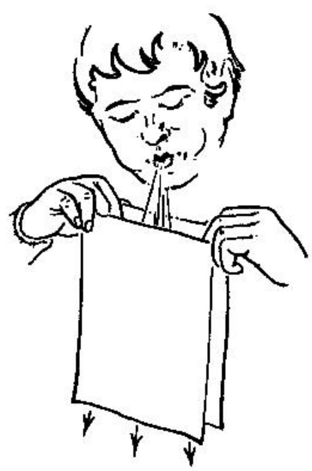
Hold it at your lower lip - the 8.5" (short) end and blow over the top. What do you notice? Did the paper rise up or fall down?

Does that seem odd to you? If you blow under the paper, it rises up, and if you blow over the top of the paper it also rises up! So what gives?

Here's what's happening:

When you blow out your mouth, you lower the air pressure right in front of your nose. When you blow over the top of the paper, you created a lower pocket of air pressure right on top of the paper. Since the higher pressure is now under the paper, and higher pressure always pushes, the paper rises up.

Now let's try another experiment. Grab two sheets of paper, and hold them a couple inches apart.



Make sure the edges of the paper line up and hold them up vertically. Make a tunnel with the papers and blow between then papers.

How is different from the last experiment?

When you blow, you form a lower air pressure region in front of your face. So now you've got higher air pressure everywhere else but in front of your face, and since higher pressure pushes, the papers go together and touch. Can you get the papers to touch simply by blowing *between* them?

You can do this with two ping pong balls, two balloons suspended by strings, anything lightweight that can move easily will show this effect of 'higher pressure pushes' when you create a lower pressure between the two objects by blowing between them.

So what's so great about moving sheets of paper and ping pong balls?

Well, if you magnify this effect to a larger scale, you can see why the wind blows and storms brew. A 'low front' is a low pressure air mass, which usually precedes a storm.

Changes in air pressure makes the winds kick up. Air moves from higher pressure to lower pressure, and this movements makes wind: "*Winds blow from high to low!*"

How does the air change pressure? There are a number of ways. Think of air pressure at sea level as being under a lot of blankets – it feels very heavy compared to only the thin blanket you'd feel at the top of a high mountain.

Since air pressure changes over time (usually caused by changes in temperature), cooler air (more dense) sinks and warmer air rises. When warm air rises, it causes an area of lower pressure, which brings in the clouds.

How Does an Airplane Fly? It's Heavier than Air!

If you wanted to fly, what do you need to do?

Now whether you said you need to strap wings onto your arms and flap really hard, or make a giant catapult large enough to toss you into the air, you're right. You need some kind of propulsion to get you going. But unless you add wings that generate lift, you're really no different than a rocket.

There are a few basic obstacles you need to overcome in order to fly. So grab your shoe or a nearby pillow or something like this that you can drop to the floor and let's do a quick experiment.

Pick up your shoe and hold it out at arm's length and let it go.

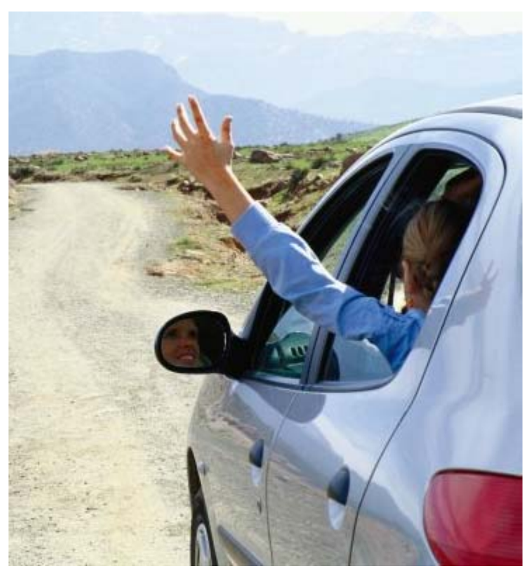
What happened? Did it stick to the ceiling? Hit the floor? Smack into the window? What happened?

Right – it hit the floor. No surprises there. But why? Because of gravity! (We covered this back in Unit 1: Lesson 2 on gravity.)

In order to start flying, you have to overcome that force. There's a number of different ways to do this, and we'll talk about this in a minute.

But first, there's another force you have to overcome if you want to fly. Imagine now you're in the backseat of your car on the freeway. Roll down the window and stick your hand out the window.

Pretend right now and hold your hand up - which way to have to hold your hand in order to feel the most amount of force against your hand? Which way does your palm have to face – palm vertical or horizontal – in order to feel the most force on your hand?



Your palm must be vertical.

What direction does your palm need to be if you want your hand to slip through the air with the least amount of force pushing on it?

Horizontal – like the picture above.

Now why is that? Why does it matter which way your hand is when you go down the freeway?

When you stick your hand out the window, you're going fast enough to feel the air molecules hit your hands. When your hand is vertical, there's more area for the molecules to smack into your hand, and you feel a higher pressure, more force on your hand – this is called 'drag force'.

When your palm is horizontal, there's less area that the wind sees, and so you feel less drag force. It's the same shape like a rocket, or airplane wing – it's very aerodynamic.

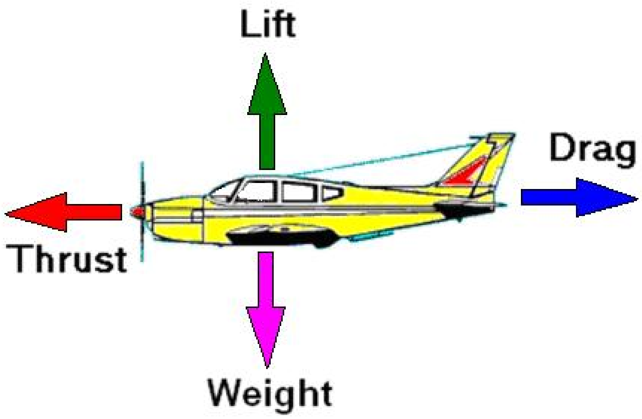
Airplanes have a few things going for it that we as humans don't have –a propeller, jet engine, or rocket, for instance. Airplanes have a method of thrust to overcome that feeling you felt on the freeway on your hand – the drag force. The larger the area that the wend sees, the higher the drag force you need to overcome.

Airplanes have a smooth shape to them that slip through the air, a lot like a fish does. To overcome drag, you add an engine to your craft. You can overcome drag by other ways, such as throwing a ball across the room – at first, the ball moves because the thrust you gave it was more than the drag force the ball experiences. It does eventually come to a stop unless you add a rocket engine to the ball or something to keep it going.

So you add engines (thrust) to overcome the drag force, but you also have to pay attention to the shape of your object.

There's another thing that airplanes have in order to fly. If all they had were engines, they'd be no different than a racecar. They have something that generates lift to counteract gravity.

But you might be wondering how to wings generate lift if they don't flap?



Here's a really fun and quick experiment you can do to demonstrate how airplanes generate lift by changing air pressure:

Point your nose to the ceiling and place the stem of the funnel in your mouth. Now place the ping pong ball into the funnel and try as hard as you can to blow the ball out of the funnel.

Can you do it? Keep your face pointed at the ceiling as you blow!

If you don't have a funnel, try a small ball (like a cheese puff) with a straw as shown above.

Here's a hint…you won't be able to! In fact, the harder you blow, the more stuck that ball is going to be in the funnel! Now you can do this with a hair dryer, too:

Here's what's going on with the funnel: when you blow, there's a small pocket of lower air pressure under the ball. The higher air pressure on top of the ball pushes down on the ball.

The harder you blow, the more you lower that air pressure under the ball! Since the ball is curved, this actually speeds up the airflow around the ball and lowers the pressure on the bottom even more!

An airplane wing is curved on top and straight on the bottom for this very reason!

The wings on an airplane use an idea from an Italian scientist named Bernoulli, and his idea was this: the faster air flows, the less time it has to push down on the surface and because of this, the air pressure is lowered.

An airplane wing has a curved surface on top to get the wind to move over the top faster, which decreases the pressure over the top of the wing. Just like with the ping pong ball, where the air moved the fastest was where the pressure was lowest. On an airplane wing, the lower air pressure is on the top of the wing.

Now we just tried a few experiments with air pressure and how higher air pressure always pushes, can you see now why an airplane flies?

Since higher pressure is now on the bottom surface, and higher pressure pushes, the wings (and also the whole airplane) go up.

Lesson 2: Geology

Everything is matter. Well, except for energy, but that's everything else. Everything you can touch and feel is matter. It is made up of solid (kind of) atoms that combine and form in different ways to create light poles, swimming pools, poodles, Jell-O and even the smell coming from your pizza.

All matter is made of atoms. Shoes, air, watermelons, milk, wombats, you, everything is made of atoms. Hundreds and billions and zillions of atoms make up everything. When you fly your kite, it's atoms moving against the kite that keep it in the air. When you float in a boat, it's atoms under your boat holding it up.

My definition of an atom is: the smallest part of stable matter.

There are things smaller than an atom, but they are unstable and can't be around for long on their own. Atoms are very stable and can be around for long periods of time. Atoms rarely hang out on their own, though. They are outgoing and usually love to get together in groups. These groups of atoms are called molecules. A molecule can be made of anywhere from two atoms to millions of atoms. Together these atoms make absolutely everything, including the minerals, crystals, and rocks we're about to study.

A periodic chart has a bunch of boxes. Each box represents one element. In each box is a ton of information about each element. All atoms are made from the same stuff; it's just the amount of stuff that makes the atoms behave the way they do.

If you look at a periodic table you will notice that there will be about 112 to 118 different elements (this will vary depending on how recently the table was created). About 90 of those occur naturally in the universe. The other ones have been man-made and are very unstable. So imagine: Everything in existence, in the entire universe, is made of one or several of only about 90 different types of atoms.

hydrogen 1 H 1.0079																		helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122												boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305												aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 **	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
**Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

Everything, from pianos to pistachios are made from the same set of 90 different Legos!

Now, if you find that amazing, listen to this: Almost everything in the universe is mostly made of only twelve different kinds of atoms! But wait, there's more.

All living things are mostly made of only five different kinds of atoms! Five! You and a hamster are made of the same stuff! All living and once-living things are made mostly of carbon, hydrogen, oxygen, nitrogen, and calcium. *Ta daa!* Those are the ingredients for life. Put 'em in a bowl, stir and voila, you can make your own penguin.

Okay, obviously it's not that easy. It takes a lot more than that to make life, but at least now you know the ingredients. An easy way to remember the main ingredients for living things is to remember the word CHONC. Each letter in CHONC is the first letter in the 5 elements carbon, hydrogen, oxygen, nitrogen and calcium.

One last interesting thing to think about here: Of all the atoms in the entire universe, 90% of them are hydrogen. Only 10% of the entire universe is made up of anything other than hydrogen.

So what does this have to do with rocks and minerals?

A mineral is inorganic, meaning that it doesn't come from carbon (C on the periodic table) compounds. Minerals are crystalline, which means their atoms form a pattern, like quartz and diamond. A crystal of pyrite is made of iron sulfide molecules that are all stacked on top of one another in a regular pattern (cubes, actually). Halite is made of cubes of sodium chloride. The thing to remember here is that most crystals are big enough to see with your eye.

Minerals are pure chemical substances, made up entirely of one molecule through and through. Examples of minerals are everywhere. Rock salt is a mineral called halite. Fool's gold is a mineral called pyrite. They are made of a single substance and nothing else. Rocks are composed of two or more minerals.

There are several different tests that geologists use on rocks to classify them. Here are the most common types of tests:

Color & Streak

Every mineral has a set of unique characteristics that geologists use to test and identify them. Some of those tests include looking at the color of the surface, seeing if the mineral is attracted to a magnet, dripping weak acids on the rock to see if they chemically react, exposing them to different wavelengths of light to see how they respond, scratching the rocks with different kinds of materials to see which is harder, and many more. There are more than 2,000 different types of minerals and each is unique. Some are very hard like diamonds, others come in every color of the rainbow, like quartz and calcite, and others are very brittle like sulfur.

The color test is as simple as it sounds: Geologists look at the color and record it along with the identification number they've assigned to their mineral or rock. They also note if the color comes off in their hands (like hematite). This works well for minerals that are all one color, but it's tricky for multi-colored minerals. For example, azurite is always blue no matter where you look. But quartz can be colorless, purple, rose, smoky, milky, and citrine (yellow).

Also, some minerals look different on the surface, but are really the same chemical composition. For example, calcite comes in many different colors, so surface color isn't always the best way to tell which mineral is which. So geologists also use a "streak test".

For a streak test, a mineral is used like a pencil and scratched across the surface of a ceramic tile (called a streak plate). The mineral makes a color that is unique for that mineral. For example, pink calcite and white calcite both leave the same color streak, as does hematite that comes in metallic silvery gray color and also deep red. This works because when the mineral, when scratched, is ground into a powder. All varieties of a given mineral have the same color streak, even if their surface colors vary. For example, hematite exists in two very different colors when dug up, but both varieties will leave a red streak. Pyrite, which looks a lot like real gold, leaves a black streak, while gold will leave a golden streak.

The tile is rough, hard, and white so it shows colors well. However, some minerals are harder than the mineral plate, like quartz and topaz, and you'll just get a scratch on the plate, not a streak.

Mohs' Hardness

The sample's hardness is determined by trying to scratch and be scratched by known materials, like pennies, steel, glass, and so forth. If the material leaves a mark on the mineral, then we know that the material *is harder than the mineral is.* We first start with a fingernail since it's easy to use and very accessible. If it leaves a mark, that means that your fingernail is harder than the mineral and you know it's pretty soft. Talc is one of the softest minerals, making it easy to scratch with your fingernail.

However, most minerals can't be scratched with a fingernail, so we can try other objects, like copper pennies (which have a hardness of 2.5-3.5), steel nail (3.5-5.5), steel knife (5.5), and even quartz (7). The most difficult part of this experiment is keeping track of everything, so it's a great opportunity to practice going slowly and recording your observations for each sample as you go along.

Cleavage & Fracture

Cleavage and fractures are two properties that geologists test at the same time, both by observations. Using a hammer, geologists will break a mineral by studying how the mineral broke. They describe the way the surfaces look. Sometimes minerals break apart like they were stacked together in thin sheets. Other times they break off in large chunks, and the sides of each chunk are always at right angles. The way that they break into planes is called "cleavage." Minerals can have cleavage in one direction, like mica, or two or three directions (like halite). The type of cleavage is also described using geometric terms. Halite has cubic cleavage because when it breaks, it looks like it's made up of tiny cubes, while calcite has rhombic cleavage because it never breaks into right angles, but always in a rhombus, or diamond shape.

Fracture describes the surfaces that are broken but don't break along plane lines. A mineral can have both cleavage and fracture, and some have either one or the other. Quartz has no cleavage, only fracture. Calcite has no fracture, only cleavage. Feldspar has both.

Geologist look for smooth surfaces, which can be (when viewed up close) cubes, triangles, or simple, flat plane surfaces. Always look for cleavage first, then fracture when making your data observations.

An easy way to look for cleavage is to hold the sample in sunlight and look for surfaces that reflect light and describe the surface in one of three ways for cleavage:

- Perfect – the mineral breaks to reflect a clear, glass, or mirror-smooth surface.
- Good – the mineral breaks to reveal a surface that reflects light, but may be dull in places.
- Poor – the mineral breaks along clear planes and flat spaces are visible, but these are dull and could be ragged, and not very reflective.

Remember, a mineral can have more than one cleavage plane. For example, feldspar has two cleavages, one which is perfect and one which ranges from poor to good, depending on the sample. At first glance, you might not be able to tell feldspar from quartz, but if you look for cleavage, you'll find feldspar has two planes of cleavage whereas quartz has none. Quartz will look like lots of broken surfaces that are not flat planes.

The way a mineral breaks depends on what the crystalline structure looks like. Here are some forms of cleavage:

- Basal cleavage is cleavage on the horizontal plane, like mica. Basal cleavage samples can sometimes have their layers peeled away.
- Cubic cleavage is found in mineral that have crystals that look like cubes., like with galena or halite.
- Octahedral cleavage is found on crystals that have eight-sided crystals, like two pyramids with their bases stuck together. Look for flat, triangular wedges that peel off an octahedron, like in the mineral fluorite.
- Prismatic cleavage is found in minerals that have four or more sides and are long in one direction, like aegirine, where the crystal cleaves on the vertical plane.
- Rhombohedral cleavage is really my favorite, because it shows up in calcite so well due to its internal crystal structure, which is made up of hexagonal crystals. No

matter where you look, there are no right angles to this cleavage – everything is at an angle.

Fracture can be described like this:

- Conchoidal (like a shell, for example: obsidian)
- Earthy (looks like freshly broken soil, like limonite)
- Hackly or jagged (when a mineral is torn, like with naturally occurring silver or copper)
- Splintery (looks like sharp, long fibrous points, like chrysolite)
- Uneven (rough surface with random irregularities, like pyrite and magnetite)
- Even or smooth (the fracture forms a smooth surface)

Acid Testing

If your sample fizzed, you've got carbonate in your sample, and your sample might be calcite, marble, coquina, or limestone. If the powder fizzed, you've probably found dolomite, which is similar to calcite except it also has magnesium, which bonds more tightly than calcium, making the sample less reactive than limestone.

The reaction doesn't always occur quickly. Sometimes you've got to be patient and wait. For example, magnetite has a weak reaction with acid, and if you grind it to a powder and then test, you have to wait half a minute for tiny bubbles to form. Magnifiers are helpful for these smaller, weaker reactions.

A lot of rocks contain small amounts of calcite or other carbonate minerals, so all of these make a fix even though carbonate is only a small part of the rock. There might be small veins or crystals of carbonate minerals that you can't even see, yet when you place a drop of acid on them, they bubble up. You can tell these types of rocks from the real thing because you won't be able to do more than one acid test on them. The second time you try to add a drop of acid, there will be no reaction. The acid test is just one of many tests used, and shouldn't be the only one that you use to determine your sample's identification.

Chemically speaking, when you add the acid to the samples, you're

dissolving the calcium in the samples and releasing carbon dioxide gas into the car (these are the bubbles you see during the reaction).

For calcium carbonate and vinegar, the reaction looks like this:

$2CH_3COOH + CaCO_3 \rightarrow Ca(CH_3COO)_2 + H_2O + CO_2$

The first term on the left CH_3COOH is the acetic acid (vinegar), and the second term $CaCO_3$ is the calcium carbonate. They both combine to give water H_2O, carbon dioxide CO_2, and calcium acetate $Ca(CH_3COO)_2$.

Carbonate minerals that react with acid (either vinegar or hydrochloric acid (HCl) as shown in the video) include aragonite, azurite, calcite, dolomite, magnetite, malachite, rhodochrosite, siderite, smithsonite, strontianite, and witherite. You can increase the reactivity with HCl by warming the HCl solution before using for the acid test.

Do not let kids test their minerals with hydrochloric acid.

(For teachers demonstrating the HCl version of this test: $CaCO_3 + 2HCl \rightarrow Ca^{++} + 2Cl^{--} + H_2O + CO_2$)

Note: a few rocks, like coquina, oolite, and tufa can produce an extreme reaction with hydrochloric acid because they have a lot of calcite, and/or a lot of pore space that allows for high surface areas (exposing more of the calcium carbonate to the acid). The reaction will be quick, foamy, and vigorous, which is why we only use *one* drop of acid at a time.

Tenacity

Tenacity is a measure of how a mineral behaves when under stress, like being crushed, bent, torn, or hammered. Minerals will react differently to each type of stress. Minerals can have more than one type of tenacity, since it's possible for a mineral to have different (or several at the same time) reactions to the stress. Here's a way to classify their response to stress:

- Brittle: The sample crumbles or turns into a powder. Most minerals are brittle, like quartz.
- Sectile: These minerals can be separated with a knife, like wax, like gypsum.
- Malleable: When you hammer the mineral and it flattens instead of breaks, it's malleable like silver and copper.

- Ductile: A mineral that can be stretched into a wire is called ductile. All true metals are ductile, like copper and gold.
- Flexible-Inelastic: When you bend a mineral and release it, it stays in the new shape. It was flexible enough to bend, but it didn't snap back into its original shape when released, like copper.
- Flexible-Elastic: When you bend a mineral and release it, it springs back into its original shape. Minerals that are flexible-elastic are fibrous, like chrysotile serpentine.

Density

Density is mass per unit volume, or ρ = m . V and it's usually measured by geologists in grams per mL.

The specific gravity (also called the "s.g." or "SG") of a mineral or rock is how we compare the weight of the sample with the weight of an equal volume of water. Low specific gravity substances, like pumice (0.9), are not very dense. High specific gravity substances, like for gold (19.3), are very dense. If the specific gravity is less than 1, it will float on water.

Density is a way to measure two different minerals that might be exactly the same size, but their weights are different. Minerals with a metallic luster tend to be heavier. You'll find variations for SG within the same minerals due to impurities of the mineral. Along those lines, this test can't be done for material that is embedded within a rock, only for a single sample.

Here are a few examples for you to compare your samples with:

- Amber 1.1
- Quartz 1.5
- Obsidian 2.5
- Amethyst 2.6
- Diamond 3.5
- Hematite 5.05
- Pyrite 5.1
- Gold 19.3

Luster

Every mineral has a particular luster, but some have different luster on different samples. Since it's gauged by eye and not a scientific instrument, there's quite a lot to be left to the observer when describing it. Luster is not usually used to identify minerals, since it's so subjective.

That said, it is useful when describing a sample's surface, so hold up yours to the light and use the descriptions below to find the one that best describes what you see.

- Metallic or splendent luster are found in highly reflective minerals, like gold.
- Submetallic luster is found in minerals that have a similar luster to metal, but it's a bit duller and less reflective. These minerals are opaque and reflect light well. You'll find submetallic luster in the thin splinter sections of minerals, such as sphalerite, cinnabar, and cuprite.
- Vitreous or glassy luster describes 70% of all minerals, and they have the luster of glass. Quartz, calcite, topaz, beryl, tourmaline, and fluorite are examples of glassy luster.
- Adamantine lusters (brilliant, like a cut diamond) are for transparent materials that show a very bright shine because they have a high refractive index.
- Resinous lusters are usually yellow, orange, or brown minerals that have high refractive indices (like the way sunlight goes through honey).
- Silky lusters have very fine fibers aligned in parallel, so it looks like a cloth of silk. Minerals like asbestos, ulexite, and a variety of gypsum called satin spar all have silky luster. If a sample has fibrous luster, it is coarser than a silky luster.
- Pearly luster minerals look like the way light reflects off pearls, like the inside an oyster shell. These types of minerals have perfect cleavage, like muscovite and stilbite. Mica also has a pearly luster. Some pearly luster minerals also have an iridescent hue.
- Greasy or oily luster looks like fat, and is found in minerals that have a lot of microscopic inclusions, like opal and cordierite. Most greasy luster minerals also *feel* oily.
- Pitchy luster looks a lot like tar, and is found in radioactive minerals.
- Waxy luster resembles wax, the way jade and chalcedony look on their surface.
- Dull or earthy luster minerals have very little or no luster at all, because they have a surface that scatters the light in all directions, like with Kaolinite. Some geologists say that earthy luster means less luster than dull, but it's really a close call between the two.

When light strikes a surface, it can be reflected off the surface, like a mirror, or it can pass through, like a window, or both. Metallic luster has most of the light bouncing off the surface, whereas calcite has most passing through the mineral.

When light travels through a mineral, it refracts, or changes speed, as it crosses the new material boundary. This is what makes the luster appear different for different materials.

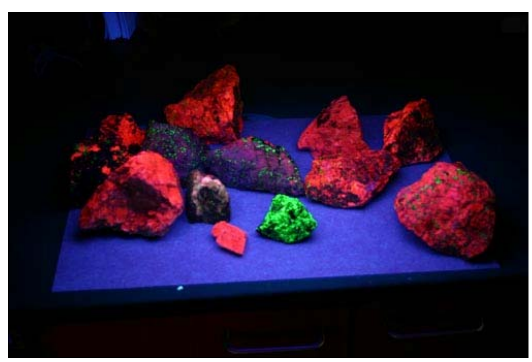
Refraction is how light bends when it travels from one substance to another. When light moves through a prism, it bends, and the amount that it bends is seen as color that comes out the other side. Each color represents a different amount of bending that it went through as it traveled through the prism.

Fluorescence

Stars, including our sun, produce all kinds of wavelengths of light, even UV. The UV minerals in this lab contain a substance that reacts with light. It takes the UV light from the sun and then re-emits it in a different wavelength that's visible to us.

When a particle of UV light hits an atom in the mineral, it collides with an electron which makes the electron jump to a higher, more ene rgetic state that is a bit further from the center of the atom than the electron is used to. That's how energy gets absorbed by an atom. The amount of energy an electron has determines how far from the atom it has to be.

The electron prefers being in its lower state, so it relaxes and jumps back down, and when it does, it transfers a blip of energy away. This blip of energy is the light we see emitted from the UV mineral. This process continues as long as we see a color coming from the mineral under the UV light.



There are two different types of UV wavelengths: longwave and shortwave. Some minerals fluoresce the same color when exposed to both wavelengths, while others only fluoresce with one type, and still others fluoresce a different color depending on which it's exposed to. Minerals fluoresce more notably with shortwave UV lamps, but these are more dangerous than longwave since they operate at a wavelength that also kills living tissue.

Shortwave UV lamps and lights should only be operated by an experienced adult. Never use a shortwave light when children are around.

Most minerals do not fluoresce, but in the ones that do, there are either small impurities that fluoresce (called "activators") or the pure substance itself fluoresces (although this is rare). For a mineral to fluoresce, the impurities present must be in just the right amount. For example, red fluorescent calcite from Franklin, NJ, USA is activated by manganese that's present, but only if there's about 3% of it in the mineral. If there's more than 5% or less than 1% manganese, the sample won't fluoresce at all. It's the amount and type of the impurities that determines the color and intensity of the fluorescence.

Fluorescence is not a reliable way to identify a mineral, since some samples will fluoresce with different colors even though they are all the same mineral. Fluorescence is used to determine where the mineral came from, since the colors that the minerals fluoresce usually match the original location of the mineral.

Phosphorescence is when a sample glows even after you turn off the UV light source. This is the type of glow you'll find in "glow in the dark" toys, where the light slowly fades after you turn off the light. Atoms continue to emit light even after the electrons return to their normal energy states. While it looks like seconds to minutes that the glow lasts, some samples have been found to phosphoresce for years using highly sensitive photographic methods. Only a few minerals phosphoresce, such as calcite from Terlingua, Texas.

Magnetism

Minerals can become attracted to a magne tic field if they are heated to a certain temperature. These minerals become ferromagnetic after heating them up. Some minerals also act as magnets when they are heated, but this effect is only temporary for as long as the mineral stays at that temperature.

Magnetism is a very useful way of identifying a mineral, because it's so precise. When testing for magnetism, you'll get better results if you use the strongest magnet you can find. You'll find minerals that respond to magnets (without heating them up first) are metallic-looking samples.

Most student-grade geology books refer to minerals that are attracted to magnetic fields as "magnetic," which leads to confusion because there's a difference between being "magnetic" (acting as a magnetic field) and being "attracted *to* magnetic fields." When you fill out your observations in the data table, keep this in mind when you write down what you see by using the words "magnetic" or "attracted to a magnetic field."

Activities and Experiments

Lesson 1: Atmosphere

Note: This is only a small selection of experiments from the lesson. For the full set of activities and experiments, visit the website.

Experiment: Fountain Bottle

Materials: small lump of clay, water, a straw, and one empty 2-liter soda bottle

Fill a 2-liter soda water bottle full of water and seal it with a lump of clay wrapped around a long straw so that the straw is secured to the mouth of the bottle. (The straw should be partly submerged in the water.) Blow hard into the straw. Splash!

What happened? As you blow air into the bottle, the air pressure increases inside the bottle. This higher pressure pushes on the water, which gets forced up and out the straw (and up your nose!).

Experiment: Squished Balloon

Materials: a balloon, one empty glass jar (not included), and scrap of paper towel , matches , and an adult

Blow up a balloon so that it is just a bit larger than the opening of the jar and can't be easily shoved in. With an adult, light the small wad of paper towel on fire and drop it into the jar. Place the balloon on top. When the fire goes out, lift the balloon. The jar goes with it!

What's going on? Fire eats air, or in more scientific terms, the air gets used up by the flame and lowers the air pressure inside the jar. The surrounding air outside the jar is now at a higher pressure than the air inside the jar and it pushes the balloon into the jar. Remember: *Higher pressure pushes!*

Experiment: Sneaky Bottles

Materials: two balloons, one tack, and two empty water bottles

Poke a balloon into a water bottle and stretch the balloon's neck covering the mouth of the bottle from the inside. Repeat with the other bottle. Using the tack, poke several small holes in the bottom of one of the water bottles. Putting your mouth to the neck of each bottle, try to inflate the balloons.

What's going on? This experiment illustrates that air really does take up space! You can't inflate the balloon inside the bottle without the holes, because it's already full of air. When you blow into the bottle with the holes, air is allowed to leak out making room for the balloon to inflate. With the intact bottle, you run into trouble because there's nowhere for the air already inside the bottle to go when you attempt to inflate the balloon.

A cool twist on this activity is to drill a larger hole in the bottle (say, large enough to be covered up by your thumb) and inflate the balloon inside the bottle with the hole left open, then plug up the hole with your thumb. The balloon will remain inflated even though its neck is not tied! Where is the higher pressure region now?

Experiment: Streaming Water

Materials: A tack, and a plastic water bottle with cap, and bathtub

Fill the bathtub and climb in. Grab your water bottle and tack and poke several holes into the lower half the water bottle. Fill the bottle with water and cap it. Lift the bottle above the water level in the tub and untwist the cap. Water should come streaming out. Close the cap and the water streams should stop. Open the cap and when the water streams out again, can you "pinch" two streams together using your fingers?

What's happening? First, you're getting clean. Second, you're playing with pressure again. Watch the water level when you uncap the bottle. As the water streams out, the water level in the bottle moves downward. Notice how the space for air increases in the top of the bottle as the water line moves down. (The air comes in through the mouth of the bottle.) When you cap on the bottle, there's no place for air to enter the bottle. The water line wants to move down, but since there's no incoming air to equalize the pressure, the flow of water through the holes stops. Technically speaking, there's a small decrease in pressure in the air pocket in the top of the bottle and therefore the air outside the bottle has a higher pressure that keeps the water in the bottle. *Higher pressure pushes!*

Experiment: Squished Soda Can

Materials : An empty soda can, water, a pan, a bowl, tongs, and a grown-up assistant

An average can of soda at room temperature measures 55 psi before you ever crack it open. (In comparison, most car tires run on 35 psi, so that gives you an idea how much pressure there is inside the can!)

If you heat a can of soda, you'll run the pressure over 80 psi before the can ruptures, soaking the interior of your house with its sugary contents. Still, you will have learned something worthwhile: adding energy (heat) to a system (can of soda) causes a pressure increase. It also causes a volume increase (kaboom!).

How about trying a safer variation of this experiment using water, an *open* can, and implosion instead of explosion?

Prepare an ice bath by putting about ½" of ice water in a shallow dish. With an adult, place a few tablespoons of water in an empty soda or beer can and place the can upright in a skillet on the stove. When the can emits a think trickle of steam, grab the can with tongs and quickly invert it into the ice dish. CRACK!

The air in the can was heated and expanded. When you cool it quickly by taking it off the stove and placing it in the ice water, the air cools down inside and shrinks, creating a lower pressure inside the can. Because the surrounding air outside of the can is now higher, it pushes on all sides of the can and crushes it.

Troubleshooting: The trick to making this work is that the can needs to be full of hot *steam*, which is why you only want to use a tablespoon or two of water in the bottom of the can. It's alright if a bit of water is still at the bottom of the can when you flip it into the ice bath. In fact, there should be some water remaining or you'll superheat the steam and eventually melt the can. You want enough water in the ice bath to completely submerge the top of the can.

Always use tongs when handling the heated can and make sure you completely submerge the top of the can in the icy water. The water needs to seal the hole in the top of the can so the steam doesn't escape. Be prepared for a good, loud *CRACK!* when you get it right.

Exercises

Lesson 1: Atmosphere

1. How does radiation travel?
    a. As a beam
    b. As a wave
    c. as a molecule

2. Where does most of the energy on earth come from?
    a. Underground
    b. The Sun
    c. The Oceans

3. What is one way that we use energy from the sun?

4. Which instrument measures humidity?
    a. Thermometer
    b. Barometer
    c. Hygrometer
    d. Rain Gauge

5. What is the unit of measurement for temperature here in the USA?
    a. Newtons
    b. Joules
    c. Fahrenheit
    d. Celsius

6. What is another unit of measurement used for temperature?
    a. Fahrenheit
    b. Celsius
    c. Joules
    d. Newtons

7. What is the science called that investigates the weather and patterns of the Earth's atmosphere?
    a. Zoology
    b. Biology
    c. Meteorology
    d. Nephology

8. What are clouds made of?
    a. Nitrogen
    b. Water
    c. Oxygen
    d. Irridium

9. What form of water exists in clouds
    a. Water vapor
    b. Liquid water
    c. Frozen water

10. What is the name of someone who studies the weather?
    a. Oncologist
    b. Herpitologist
    c. Climatologist
    d. Meteorologist
    e. Asteroidologist

11. What is the type of energy that comes from the sun?
    a. Potential
    b. Kinetic
    c. Electronic
    d. Radiation

12. What principle describes how pressure behaves in a moving fluid?
   a. Avogadro's Principle
   b. Bernoulli's Principle
   c. Boyle's Law
   d. Pascal's Wager

13. A higher pressure will ________ an object.

14. An object experiences pressure in the Earth's atmosphere in which direction more?
   a. Upwards
   b. Downwards
   c. Equally in all directions

15. If an object is higher in altitude above the earth, it experiences which pressure in relationship to an object at sea level?
   a. Greater Pressure
   b. Less Pressure
   c. Equal Pressure

Exercises

Lesson 2: Geology

1. What is the definition of a rock?
2. What does it mean if there's no streak left on the streak plate?
3. Give an example of a kind of rock that leaves a streak a different color than its surface color.
4. If a mineral scratches a penny but doesn't get scratched by a nail, can you approximate its hardness?
5. Give examples of the hardest and softest minerals on the Mohs' Scale of Hardness.
6. Name three properties geologists look for when they try to categorize a mineral.
7. If you break a sample of quartz and find that it has no clean surfaces of separation, what kind of cleavage does it show?
8. What are two things we use coal for?
9. What is the equation for finding density?
10. How is fluorescence different from phosphorescence?
11. Is lodestone the same as magnetite?
12. Name three characteristics of pumice.
13. What is a crystal, and how is it different from a mineral and a rock?

Answers to Exercises

Answers to Lesson 1: Atmosphere

1. How does radiation travel? (as a wave)
2. Where does most of the energy on earth come from? (the Sun)
3. What is one way that we use energy from the sun? (appropriate energy answer)
4. Which instrument measures humidity? (Hygrometer)
5. What is the unit of measurement for temperature here in the USA? (Fahrenheit)
6. What is another unit of measurement used for temperature? (Celsius)
7. What is the science called that investigates the weather and patterns of the Earth's atmosphere? (Meteorology)
8. What are clouds made of? (Water)
9. What form of water exists in clouds (Water vapor)
10. What is the name of someone who studies the weather? (Meteorologist)
11. What is the type of energy that comes from the sun? (Radiation)
12. What principle describes how pressure behaves in a moving fluid? (Bernoulli's principle)
13. A higher pressure will ________ an object. (Push on)
14. An object experiences pressure in the Earth's atmosphere in which direction more? (Equally in all directions)
15. If an object is higher in altitude above the earth, it experiences which pressure in relationship to an object at sea level? (Less pressure)

Answers to Exercises

Answers to Lesson 2: Geology

1. What is the definition of a rock? (Something that is made of two or more minerals.)
2. What does it mean if there's no streak left on the streak plate? (The mineral is harder than the streak plate, which means it has a hardness of above 7.)
3. Give an example of a kind of rock that leaves a streak a different color than its surface color. (Pyrite is gold, but its streak is green-black.)
4. If a mineral scratches a penny but doesn't get scratched by a nail, can you approximate its hardness? (Over 5.5)
5. Give examples of the hardest and softest minerals on the Mohs' Scale. (Diamond = 10, Talc = 1)
6. Name three properties geologists look for when they try to categorize a mineral. (Color, hardness, fluorescence, magnetism, luster, how they break, if they react to acid, etc.)
7. If you break a sample of quartz and find that it has no clean surfaces of separation, what kind of cleavage does it show? (none)
8. What are two things we use coal for? (heating water and generating electricity)
9. What is the equation for finding density? (density = m/V)
10. How is fluorescence different from phosphorescence? (Minerals that are fluorescent glow when exposed to a UV light. Minerals that continue to emit light even after the UV light has been switched off are phosphorescent.)
11. Is lodestone the same as magnetite? (Lodestone is the magnetic version of magnetite.)
12. Name three characteristics of pumice. (light-colored, floats on water, and is porous.)
13. What is a crystal, and how is it different from a mineral and a rock? (Crystals are a structure of a regular pattern of atoms within a solid. A mineral is an inorganic substance. All minerals are crystalline. Rocks are composed of two or more minerals. Not all crystals are minerals.)