

THE PERIODIC TABLE

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THE PERIODIC TABLE

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INTRODUCTION

This Teacher's Guide accompanies Program Twelve, "Periodic Table," from the Simply Science series.

Simply Science is a series of twenty-five science programs for high school students. These instructional programs use practical applications as context to the interdisciplinary concept development emphasizing the connections among science, technology, and society. This comprehensive Teacher's Guide and accompanying blackline master activity sheets provide extended practice and additional learning opportunities.

PROGRAM SUMMARY

"Periodic Table" reviews our knowledge of the atom. It begins with Mendeleev's chart of the elements, an early periodic table that organized observations made by many people. In order to explain why the behavior of elements was repetitive, we required knowledge of the atom. Various scientists helped to refine the atomic model. Bohr's model explained many of the patterns of the periodic table.

LINKS TO CURRICULUM STANDARDS

"Periodic Table" correlates with the following National Science Education Standards for grades 9-12:

Physical Science: Structure of atoms

- Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons holds the atom together.
- The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons. When an element has atoms that differ in the number of neutrons,

these atoms are called different isotopes of the element.

Physical Science: Structure and properties of matter

- Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element.
- An element is composed of a single type of atom. When elements are listed in order according to the number of protons (called atomic number), repeating patterns of physical and chemical properties identify families of elements with similar properties. This "Periodic Table" is a consequence of the repeating pattern of outermost electrons and their permitted energies.
- Bonds between atoms are created when electrons are paired up by being transferred or shared. A substance composed of a single kind of atom is called an element. The atoms may be bonded together into molecules or crystalline solids. A compound is formed when two or more kinds of atoms bind together chemically.

Physical Science: Chemical reactions

- A large number of important reactions involve the transfer of either electrons (oxidation/reduction) or hydrogen ions (acid/base reactions) between reacting ions, molecules, or atoms. In other reactions, chemical bonds are broken by heat or light to form very reactive radicals with electrons ready to form new bonds. Radical reactions control many processes such as the presence of ozone and greenhouse gases in the atmosphere, burning and processing of fossil fuels, the formation of polymers, and explosions.

PRE-TEST

A Pre-Test is included with the Blackline Masters for this program. It is meant to be administered before the video and its ensuing activities are used. This assessment tool allows you to gauge student comprehension of the Objectives before completing the lesson; its results may be contrasted with those of the Post-Test, also included herein, to assess comprehension of the Objectives after completing the lesson.

TEACHER PREPARATION/INSTRUCTIONAL NOTES

Before presenting this lesson to your students we suggest that you preview the video and review this guide, and the accompanying blackline master activities in order to familiarize yourself with their content.

As you review the materials presented in this guide, you may find it necessary to make some changes, additions, or deletions to meet the specific needs of your class. We encourage you to do so, for only by tailoring this program to your class will they obtain the maximum instructional benefits afforded by the materials.

It is also suggested that the video presentation take place before the entire group under your supervision. The lesson activities grow out of the context of the video, therefore, the presentation should be a common experience for all students.

STUDENT OBJECTIVES

After viewing the video and participating in the follow-up activities, students will be able to:

- Explain how the elements are organized on the periodic table.
- Predict the properties of elements based on their position on the periodic table.
- Predict the placement of elements on the periodic table based on their properties.
- Predict the formula of some simple, two-element compounds based on the valence of the atoms.

STUDENT PREPARATION

This video is one of a series. Before students view this program and complete the follow-up activities, they should be able to:

1. Identify the three particles which make up an atom.

Atoms are composed of protons, neutrons, and electrons.

2. Explain what is meant by a “family” of elements.

A family consists of elements that share similar chemical properties. They will react in a similar way. The halogens are a family.

3. Find a “group” of elements on the periodic table.

A group of elements is identical to a family; they form vertical columns on the periodic table.

4. Explain why the modern table of the elements is called a “periodic” table.

Periodic refers to the fact that the chemical properties of the elements repeat at intervals, corresponding to groups.

If students have difficulty with any of the items, you should review the concepts in reference materials before viewing the video.

BLACKLINE MASTERS

The following blackline master activity sheets are included with this guide. Duplicate and distribute those you wish to use. An Answer Key appears on pages 5-9.

(1.) **Blackline Master #1: Pre-Test** is to be given to your students prior to viewing the video to assess their prior knowledge of the topic. It may be contrasted to **Blackline Master #8: Post-Test** to gauge student comprehension of the Objectives after the lesson has been completed.

(2.) **Blackline Master #2: Glossary** is a list of terms from the video. Students may find this handout helpful when completing the activities which accompany this lesson, as well as for preparation for the Post-Test.

- (3.) **Blackline Master #3: The First Periodic Table** explores Mendeleev's 1872 version of the periodic table.
- (4.) **Blackline Masters #4a-4b: Early Nuclear Theory** explores Dalton's and Rutherford's models of the atom and defines isotopes.
- (5.) **Blackline Masters #5a-5b: Bohr's Model of the Atom** examines the Bohr Model, including ionic and covalent bonds.
- (6.) **Blackline Masters #6a-6b: Exploring the Modern Periodic Table** is a roadmap to the modern table of elements.
- (7.) **Blackline Masters #7a-7b: Using the Modern Periodic Table** details diagrams that help predict reactions between elements.
- (8.) **Blackline Masters #8a-8c: Post-Test** is an assessment tool to be used after the video and follow-up activities have been completed. The test is based directly on the Student Objectives for this program and the National Science Education Standards for grades 9-12.

ANSWER KEY

Blackline Master #1: Pre-Test

- 1.F
- 2.F
- 3.T
- 4.F
- 5.F
- 6.F
- 7.T
- 8.T
- 9.T
- 10.T

Blackline Masters #3-7

Note that some of these questions have more than one possible answer.

1. All of these are malleable – they are easy to shape and form, yet strong. They are relatively unreactive; only silver reacts readily with oxygen in the air, but the “tarnish” is easily removed.
2. All these elements would appear in the same column – the same family or group.
3. The atomic number is equal to the number of protons or electrons in the neutral atom.
4. Mass number is the sum of protons and neutrons in the atom.
5. Protons and neutrons are found in the nucleus.
6. Carbon-14 has six protons and eight neutrons.
7. Potassium-39 has 19 protons and 20 neutrons.
8. Aluminum has atomic number 13.
9. Atomic mass unit (amu) is equal to 1/12 the mass of a carbon-12 atom.
1 amu = 1.6605×10^{-24} g
10. The ratio is 1:1; protons and neutrons have the same mass.

11.

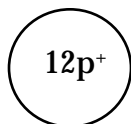
Element Name	Symbol	Atomic Number	Number of Protons	Number of Neutrons
aluminum	Al	13	13	14
chlorine	Cl	17	17	18
nitrogen	N	7	7	7
calcium	Ca	20	20	20

12. Metals react with non-metals to form ionic bonds.
13. Non-metals react with non-metals to form covalent bonds.

14. -- 2e⁻ --

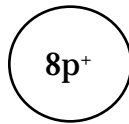
-- 8e⁻ --

-- 2e⁻ --



-- 6e⁻ --

-- 2e⁻ --



magnesium atom

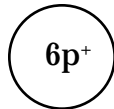
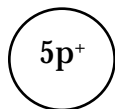
oxygen atom

15. -- 3e⁻ --

-- 4e⁻ --

-- 2e⁻ --

-- 2e⁻ --



boron atom

carbon atom

-- 3e⁻ --

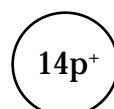
-- 4e⁻ --

-- 8e⁻ --

-- 8e⁻ --

-- 2e⁻ --

-- 2e⁻ --



aluminum atom

silicon atom

16. Phosphorus - 3; arsenic - 4;
antimony - 5

17. Hydrogen - 1; calcium - 2;
chlorine - 7

18. The element is oxygen.

19. Generally metallic elements will form alloys.

20. a. covalent bond
b. ionic bond
c. ionic bond
d. covalent bond

21. $\text{LiCl}_{(s)}$
22. $\text{BeCl}_{2(s)}$
23. $\text{NF}_{3(g)}$
24. Aluminum and magnesium are both metals. Aluminum has three valence electrons, magnesium has two. They will not react with each other because both must lose electrons to become more stable. That cannot occur in a chemical reaction; if one species loses electrons the other must gain them.
25. The product of the fuel cell, in addition to energy, is water. There are no emissions such as carbon monoxide, carbon dioxide and various oxides of nitrogen and sulfur which have negative effects on air quality and the environment in general.

Blackline Masters #8a-8c: Post-Test

Multiple Choice

1. b. John Newlands
2. d. germanium
3. c. James Chadwick
4. b. covalent bond

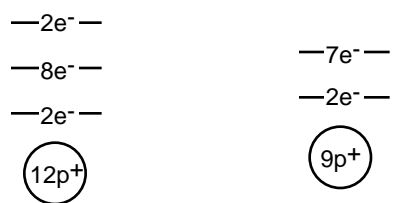
Long Answer

1. positive; nucleus
2. protons; nucleus
3. atomic number
4. periodically repeating chemical properties.
5. He proposed that atomic electrons could only exist in stable, well defined allowed energy levels. He used the quantum theory to support his model.
6. donors; lose electrons
7. share; a covalent bond
8. 6; 6; 8
9. follow the periodic law closely; alkali metals; alkali-earth metals; halogens; noble gases
10. 4; 6
11. strontium loses two electrons becoming a positively charged ion
oxygen gains two electrons becoming a negatively charged ion

the oppositely charged ions are attracted – an ionic bond

strontium and oxygen form an ionic compound

12.



magnesium atom fluorine atom

13. **valence; more stable**

14. **transition elements**

15. **55; 78**

16. **halogen**

SCRIPT OF NARRATION

DARREN: TURNING ALL THESE PARTS INTO A HIGH-TECH MOUNTAIN BIKE IS A BIT OF A PUZZLE. BUT AT LEAST I KNOW WHAT IT'S SUPPOSED TO LOOK LIKE WHEN I'M FINISHED. IMAGINE GETTING BOXES OF PARTS AND HAVING NO IDEA WHAT THE FINISHED PRODUCT WAS GOING TO BE. NOW THERE'S A CHALLENGE! EARLY SCIENTISTS DIDN'T HAVE AN EASY JOB. THEY WERE TRYING TO MAKE SENSE OF MOUNTAINS OF "SPARE PARTS," IN THE FORM OF OBSERVATIONAL EVIDENCE. NOBODY KNEW THE STRUCTURE OF THE ATOM OR THE PERIODIC TABLE. SO THEY STARTED BY ASKING SOME GOOD QUESTIONS. WHAT'S THE SIGNIFICANCE OF PATTERNS AMONG THE ELEMENTS? CAN THEORY OF THE ATOM EXPLAIN THE ORGANIZATION OF THE PERIODIC TABLE? AND WHAT DOES THE PERIODIC TABLE ALLOW US TO PREDICT ABOUT THE ELEMENTS AND CHEMICAL REACTIONS? WELL, QUESTIONS LIKE THESE ARE SIMPLY THE "NUTS AND BOLTS" OF SCIENCE!

SARAH: THE FIRST PART OF THE PUZZLE WAS TO FIND PATTERNS AMONG THE ELEMENTS, AND ARRANGE THEM IN A LOGICAL WAY. IN 1864, A SCIENTIST NAMED JOHN NEWLANDS STATED THE PERIODIC LAW.

JULIEN: IN 1872, DMITRI MENDELEEV ORGANIZED THE KNOWN ELEMENTS INTO THE FIRST USABLE PERIODIC TABLE.

LAUREEN: IT WORKS LIKE THIS. ELEMENTS ARE LISTED FROM LEFT TO RIGHT IN ORDER OF INCREASING ATOMIC MASS, RELATIVE TO HYDROGEN.

JULIEN: BUT MENDELEEV BREAKS THEM INTO A NEW ROW WHEN CHEMICAL PROPERTIES REPEAT.

LAUREEN: LIKE SODIUM AND POTASSIUM, FOR INSTANCE.

JULIEN: YEAH. THEY HAVE SIMILAR PHYSICAL AND CHEMICAL PROPERTIES, SO THEY BELONG TO A VERTICAL GROUP OF SIMILAR ELEMENTS.

LAUREEN: AND SINCE THE PROPERTIES REPEAT PERIODICALLY, WE CALL THIS "THE PERIODIC TABLE".

DARREN: MENDELEEV'S TABLE HAD GAPS IN IT, AND HE PREDICTED THAT THESE WERE UNKNOWN ELEMENTS. ONE OF

THESE ELEMENTS HE CALLED EKA-SILICON. SO WHEN ELEMENTS LIKE GERMANIUM — WHICH FOLLOWS SILICON — WERE DISCOVERED AND MATCHED THE PROPERTIES MENDELEEV PREDICTED, HE BECAME FAMOUS. MENDELEEV HAD FOUND PATTERNS AMONG THE ELEMENTS. BUT AT THE TIME, NOBODY COULD EXPLAIN THE BIG PICTURE. BY THE EARLY 1900'S, SCIENTISTS HAD FOUND A CRITICAL PART OF THE PUZZLE, THE NUCLEAR MODEL OF THE ATOM. ERNEST RUTHERFORD DISCOVERED THAT THE ATOM HAD A TINY NUCLEUS CONTAINING POSITIVELY CHARGED "PROTONS," WITH AN EQUAL NUMBER OF NEGATIVELY CHARGED "ELECTRONS" ORBITING AROUND IT. MOST OF THE ATOM WAS EMPTY SPACE. BUT THE TINY NUCLEUS HAD A HUGE MASS! ACCORDING TO RUTHERFORD'S CALCULATIONS, THE NUCLEUS OF THE ATOM WAS ABOUT ONE TEN-THOUSANDTH OF THE TOTAL SIZE OF THE ATOM.

SARAH: SOON AFTER, A STUDENT OF RUTHERFORD'S, H.G.J. MOSELEY, DEMONSTRATED THAT AS WE MOVE FROM ONE ELEMENT TO THE NEXT IN MENDELEEV'S TABLE, THE POSITIVE CHARGE IN THE NUCLEUS GENERALLY INCREASES BY ONE UNIT. HE CALLED THIS THE "ATOMIC NUMBER" — THE NUMBER OF PROTONS CONTAINED IN THE NUCLEUS. THAT SOLVED THE PROBLEM OF SOME ELEMENTS NOT LINING UP WITH THEIR FAMILIES WHEN THEY WERE ORDERED ACCORDING TO INCREASING ATOMIC MASS. AND THAT'S WHY WE NOW ORDER THE ELEMENTS USING ATOMIC NUMBER INSTEAD OF RELATIVE ATOMIC MASS.

DARREN: BUT PROTONS COULDN'T ACCOUNT FOR THE TOTAL MASS OF THE ATOM. AND ELECTRONS HAVE PRACTICALLY NO MASS AT ALL. SO RUTHERFORD PREDICTED — AND JAMES CHADWICK PROVED — THAT NEUTRONS ALSO EXIST IN THE NUCLEUS. THESE ARE HEAVY, NEUTRALLY CHARGED PARTICLES THAT ACCOUNT FOR THE MISSING MASS. BY SCIENTIFIC CONVENTION, THE MASS OF A PROTON OR A NEUTRON IS DEFINED AS 1/12 THE MASS OF A CARBON-12 ATOM. THIS IS CALLED AN "AMU," AN "ATOMIC MASS UNIT." THE TOTAL MASS OF AN ATOM IS THE SUM OF THE AMU OF ALL THE PROTONS AND NEUTRONS IN THE NUCLEUS.

SARAH: THE NUMBER OF PROTONS IN THE ATOM OF AN ELEMENT IS CONSTANT. BUT THE NUMBER OF NEUTRONS CAN VARY. THE ATOMS OF ELEMENTS WITH VARIATIONS IN THE NUMBER OF NEUTRONS ARE CALLED ISOTOPES. CARBON, IN ITS MOST COMMON FORM, HAS SIX PROTONS AND SIX NEUTRONS IN THE NUCLEUS. SO WE CALL IT CARBON-12. BUT THERE ARE ALSO LESS COMMON CARBON ISOTOPES WITH ONE OR TWO EXTRA NEUTRONS, CALLED CARBON-13 AND CARBON-14. ISOTOPES LIKE THESE HAVE VARIATIONS IN THEIR MASS BECAUSE OF THE EXTRA NEUTRONS.

DARREN: IN SPITE OF ALL THESE DISCOVERIES, THE ATOMIC MODELS COULDN'T EXPLAIN WHY ELEMENTS HAD REPEATING CHEMICAL PROPERTIES. THERE WAS STILL WORK TO BE DONE.

MAY YEW: MOUNTAIN BIKERS ARE LOOKING FOR A VERY LIGHTWEIGHT BIKE. THEY WANT TO BE ABLE TO RIDE THEIR BIKES FAST, AND THEY WANT TO BE ABLE TO GET UP HILLS FAST. SO THE LIGHTER THE BIKE, THE FASTER THEY'LL GO. THE MATERIALS THE INDUSTRY IS USING RIGHT NOW ARE CHROMOLY, ALUMINUM, AND CARBON FIBER — AND CHROMOLY BEING THE MOST POPULAR. CHROMOLY IS A TYPE OF STEEL. IT'S QUITE A BIT STRONGER THAN STEEL. IT'S ABOUT TEN TIMES STRONGER THAN STEEL. AND IT'S ALSO MUCH LIGHTER. SO THEY USE CHROMOLY BECAUSE IT'S ALSO CHEAPER THAN USING ALUMINUM OR CARBON FIBER. IF YOU WEIGH ONE OF OUR CHROMOLY BIKES, THEY WEIGH IN AT BETWEEN 27 POUNDS, AND AS LIGHT AS 25 POUNDS, 24 POUNDS. THAT'S VERY LIGHT FOR A CHROMOLY BIKE. THE ALUMINUM BIKES WEIGH FROM 24 TO 26 POUNDS. AND THE CARBON FIBER BIKES CAN WEIGH AS LITTLE AS 18 POUNDS.

DARREN: IN 1913, A SCIENTIST NAMED NIELS BOHR PUT TOGETHER A NUMBER OF EXISTING IDEAS IN A TOTALLY NEW WAY. NOW, THE BOHR MODEL OF ATOMIC STRUCTURE WAS THE FIRST TO EXPLAIN REACTIVITY AND PERIODICITY ON THE PERIODIC TABLE. IT'S ALL ABOUT THE INTERACTION OF ENERGY AND ELECTRONS.

JULIEN: BOHR'S MODEL OF THE ATOM SHOWS US THAT ELECTRONS EXIST IN SPECIFIC ORBITS OR ENERGY LEVELS.

LAUREEN: THE ELECTRONS IN THE OUTER LEVEL HAVE THE MOST ENERGY. IF THE OUTER LEVEL IS FILLED, THE ATOM IS STABLE.

JULIEN: IF THE OUTER LEVEL ISN'T FILLED, THEN THE ATOM IS REACTIVE BECAUSE IT'S TRYING TO REACH A STABLE STATE.

SARAH: BOHR MADE USE OF A THEORY THAT ENERGY EXISTS IN TINY PACKETS. EACH SMALL BUNDLE OF ENERGY IS CALLED A "QUANTUM." IF AN ELECTRON ABSORBS A QUANTUM OF ENERGY, IT CAN MOVE TO A HIGHER ORBIT — A HIGHER ENERGY LEVEL. IF IT RELEASES A QUANTUM OF ENERGY, IT CAN MOVE TO A LOWER ENERGY LEVEL. BOHR ALSO FOUND THAT THE FIRST THREE ORBITS AROUND A NUCLEUS CONTAIN TWO, EIGHT, AND EIGHT ELECTRONS.

LAUREEN: ELECTRONS IN THE HIGHEST ENERGY LEVEL, FARTHEST AWAY FROM THE NUCLEUS, ARE INVOLVED IN CHEMICAL REACTIONS AND BONDING.

JULIEN: WE CALL THESE "VALENCE ELECTRONS".

SARAH: IN CHEMICAL REACTIONS, METALS ARE ELECTRON DONORS. THEY TRY TO GIVE AWAY ALL VALENCE ELECTRONS TO GET TO A STABLE STATE — A COMPLETED INNER LEVEL. NON-METALS ARE ELECTRON ACCEPTORS. THEY TRY TO GAIN EXTRA VALENCE ELECTRONS TO FILL THEIR OUTER LEVEL AND REACH A STABLE STATE.

DARREN: WHEN CHEMICALS REACT, EXISTING BONDS ARE BROKEN AND NEW ONES ARE FORMED. BUT WHAT ARE THE DIFFERENT KINDS OF CHEMICAL BONDS? SODIUM CHLORIDE, TABLE SALT, IS AN EXAMPLE OF A COMPOUND WHICH EXHIBITS AN IONIC BOND.

LAUREEN: METALLIC AND NON-METALLIC ATOMS COMBINE BY TRANSFERRING VALENCE ELECTRONS. WE CALL THESE "IONIC BONDS."

JULIEN: BY TRANSFERRING ELECTRONS, BOTH ATOMS END UP WITH A FULL OUTER LEVEL, WHICH MAKES THEM STABLE. AND AS A RESULT, THE TWO ATOMS ARE CHANGED TO IONS, WHICH HAVE OPPOSITE CHARGES.

LAUREEN: METALS FORM POSITIVELY CHARGED IONS, AND NON-METALS FORM NEGATIVELY CHARGED IONS.

JULIEN: OPPOSITE CHARGES ATTRACT. SO THE IONS ARE AT-

TRACTED TO ONE ANOTHER.

LAUREEN: WE CALL THE RESULT AN “IONIC COMPOUND.”

DARREN: SULFUR DIOXIDE IS AN INDUSTRIAL EMISSION LINKED TO ACID RAIN. IT’S AN EXAMPLE OF A COMPOUND EXHIBITING A COVALENT BOND.

LAUREEN: NON-METALLIC ATOMS COMBINE BY SHARING VALENCE ELECTRONS. WE CALL THESE “COVALENT BONDS.”

JULIEN: BY SHARING ELECTRONS, THE ATOMS MANAGE TO FILL THEIR OUTER LEVELS TO BECOME MORE STABLE.

LAUREEN: THE RESULT IS A “MOLECULAR COMPOUND.” IN THIS CASE, IT’S SULFUR DIOXIDE.

KAREN: WHAT MAKES SOME METALS STRONG, LIKE STEEL, AND SOME NOT SO STRONG, LIKE COPPER?

LEN THOMPSON: TYPICALLY, METALS’ PROPERTIES ARE BASED ON THEIR MICROSTRUCTURE, OR THE STRUCTURE IN THE STEEL, WHICH WE CAN SEE AT THE MICROSCOPIC LEVEL. MATERIALS LIKE IRON AND COPPER ARE PURE METALS; AND THEY HAVE A CONTINUOUS, UNIFORM TYPE STRUCTURE. ALLOYS ARE A LITTLE BIT DIFFERENT. THEY HAVE A DISCONTINUOUS TYPE OF STRUCTURE. STEEL, FOR EXAMPLE, IS A MIXTURE OF IRON AND CARBON. THE CARBON FORMS AS CARBIDES IN THE MATERIAL. AND WE GET A HARD, BRITTLE MATERIAL IN HERE, MIXED IN WITH THE CONTINUOUS STRUCTURE OF STEEL, WHICH INCREASES THE STRENGTH AND HARDNESS OF THE STEEL.

KAREN: HOW ARE ALLOYS LIKE THAT USED?

LEN THOMSON: TYPICALLY, ALLOYS ARE USED OR DETERMINED BASED ON THEIR PROPERTIES. IF WE LOOK AT A STAINLESS STEEL APPLICATION — IN YOUR KITCHEN, FOR EXAMPLE — A KITCHEN SINK IS MADE OF STAINLESS STEEL FOR ITS CORROSION RESISTANCE. ALSO, A BUTCHER KNIFE BLADE IS MADE FROM STAINLESS STEEL FOR CORROSION RESISTANCE. THE DIFFERENCE BETWEEN THE TWO IS A KITCHEN SINK MATERIAL MUST BE

RELATIVELY SOFT AND DUCTILE SO THAT IT CAN BE FORMED OR PRESSED OUT OF A SINGLE PLATE, WHILE A BUTCHER KNIFE BLADE MUST BE VERY HARD AND WEAR-RESISTANT TO MAINTAIN ITS SHARPNESS AFTER SEVERAL USES.

DARREN: USING BOHR'S MODEL OF THE ATOM, WE CAN FIGURE OUT THE STRUCTURE OF THE ELEMENTS. AND THAT HELPS EXPLAIN WHY THE PERIODIC TABLE WORKS.

SARAH: LET'S COMPARE MENDELEEV'S TABLE WITH THIS MODERN PERIODIC TABLE. WHAT ARE SOME SIMILARITIES AND DIFFERENCES?

JULIEN: WELL, THEY BOTH ORGANIZE THE ELEMENTS INTO VERTICAL GROUPS AND HORIZONTAL PERIODS.

SARAH: THAT'S TRUE.

LAUREEN: BUT THE ELEMENTS IN THE MODERN TABLE ARE LISTED FROM LEFT TO RIGHT, IN ORDER OF THEIR ATOMIC NUMBER — THE NUMBER OF PROTONS IN THE NUCLEUS.

JULIEN: THAT'S A CHANGE.

SARAH: RIGHT! MENDELEEV USED RELATIVE ATOMIC MASS.

JULIEN: THE ORDER OF THE ELEMENTS ISN'T ALL THAT DIFFERENT, AT LEAST IN SOME PERIODS.

LAUREEN: YEAH. FOR EXAMPLE, LOOK AT PERIOD #2: LITHIUM, BERYLLIUM, BORON, CARBON, NITROGEN, OXYGEN, AND FLUORINE. IT'S A PERFECT MATCH WITH THE MODERN TABLE.

JULIEN: EXCEPT FOR NEON, WHICH HADN'T BEEN DISCOVERED YET.

SARAH: RIGHT! A LOT OF ELEMENTS WEREN'T KNOWN WHEN MENDELEEV WAS DOING HIS WORK.

LAUREEN: THE PERIODS ON BOTH TABLES BREAK IN THE SAME PLACES, WHERE THE CHEMICAL PROPERTIES OF THE ELEMENTS REPEAT.

JULIEN: SO THERE ARE GROUPS OF ELEMENTS WITH SIMILAR CHEMICAL PROPERTIES.

SARAH: SO HOW WELL DO THE GROUPS MATCH UP?

LAUREEN: PRETTY GOOD. FOR INSTANCE, THIS GROUP RIGHT HERE: FLUORINE, CHLORINE, BROMINE, IODINE, AND ASTATINE.

JULIEN: MENDELEEV HAS FLUORINE, CHLORINE, BROMINE, AND IODINE IN A GROUP.

SARAH: AND ASTATINE WASN'T KNOWN AT THE TIME.

LAUREEN: BUT HERE'S A MAJOR DIFFERENCE. THESE ELEMENTS HERE, WHICH ARE METALS LIKE IRON AND COPPER,

ARE IN THE MIDDLE OF THE MODERN TABLE.

JULIEN: AND ANOTHER THING...HOW COME THESE TWO EXTRA ROWS ARE UNDERNEATH THE MAIN TABLE?

SARAH: ON THE MODERN PERIODIC TABLE, EVERY ELEMENT IS SEQUENCED BY ITS ATOMIC NUMBER. THAT PUTS THE "SHADED" METALLIC ELEMENTS FROM MENDELEEV'S TABLE IN THE CENTER OF THE MODERN PERIODIC TABLE. THESE ARE CALLED THE "TRANSITION ELEMENTS." OTHER SECTIONS AND GROUPS HAVE SPECIAL NAMES, AS WELL. THE ELEMENTS AT BOTH SIDES OF THE TABLE ARE CALLED "REPRESENTATIVE ELEMENTS," BECAUSE THEY FOLLOW THE PERIODIC LAW VERY CLOSELY. THESE INCLUDE THESE TWO EXTRA ROWS AT THE BOTTOM ARE THE THEY'VE ONLY BEEN MOVED OUT OF THE TABLE FOR CONVENIENCE, SO WE CAN FIT THE ENTIRE TABLE ON A SINGLE PAGE.

LAUREEN: ANOTHER THING WE NOTICE IS THAT MENDELEEV'S TABLE DOESN'T HAVE A NEAT DIVIDING LINE BETWEEN METALS AND NON-METALS.

JULIEN: BUT IN THIS MODERN TABLE, THE ELEMENTS ON THE LEFT-HAND SIDE ARE METALS. AND THE ELEMENTS ON THE RIGHT-HAND SIDE, HERE, ARE NON-METALS.

SARAH: GOOD OBSERVATION! THE LINE DIVIDING METALS AND NON-METALS IN THE MODERN PERIODIC TABLE IS CALLED THE STAIRCASE LINE BECAUSE OF ITS SHAPE. NOTE THAT METALLOIDS STRADDLE THE STAIRCASE LINE. ONE THING THE BOHR MODEL ALLOWS US TO DO IS DRAW MODELS OF INDIVIDUAL ATOMS. HOW WOULD YOU DRAW, SAY, AN ATOM OF ARGON?

LAUREEN: WELL, WE KNOW ARGON IS A NOBLE GAS.

SARAH: WHICH MEANS THE OUTER LEVEL IS FILLED.

JULIEN: AND ITS ATOMIC NUMBER IS 18, WHICH MEANS IT HAS 18 PROTONS, AS WELL AS 18 ELECTRONS.

SARAH: AND 18 OR MORE NEUTRONS, DEPENDING ON THE ISOTOPE.

JULIEN: SO THE NUCLEUS HAS 18 PROTONS, AS WELL AS 18 OR MORE NEUTRONS.

LAUREEN: AND ELECTRONS, IN LEVELS OF TWO, EIGHT, AND EIGHT, ADDING UP TO 18.

SARAH: RIGHT. NOW, HOW DO THE ENERGY LEVELS OF THE ELECTRONS FIT IN WITH ARGON'S POSITION ON THE PERIODIC TABLE?

JULIEN: WELL, THREE ENERGY LEVELS.

LAUREEN: IT'S IN ROW #3, SO THAT MEANS IT'S IN PERIOD #3.

JULIEN: SO THE PERIOD TELLS US HOW MANY ENERGY LEVELS EACH ELEMENT HAS.

SARAH: YOU'VE GOT IT! BOHR'S MODEL EXPLAINS WHY THE ELEMENTS BREAK INTO PERIODS — BECAUSE OF THE NUMBER OF OCCUPIED ENERGY LEVELS THEY HAVE.

LAUREEN: SO LITHIUM WOULD HAVE TWO ENERGY LEVELS. THAT'S WHY IT'S IN PERIOD #2.

JULIEN: AND IODINE FITS INTO PERIOD #5, WHICH MEANS IT HAS FIVE ENERGY LEVELS.

SARAH: RIGHT. THAT'S HOW IT WORKS!

KAREN: THESE MULTIVITAMINS CONTAIN ELEMENTS FROM THE PERIODIC TABLE: CALCIUM, IRON, AND POTASSIUM. WHY IS THAT?

ALYSON LEWIS: WELL, SOME OF THE ELEMENTS YOU MAY FIND ON THE PERIODIC TABLE ARE ALSO RESPONSIBLE FOR HELPING US MAINTAIN GOOD HEALTH. NOW, IT'S ALWAYS BEST IF YOU CAN FOLLOW A GOOD, HEALTHY WAY OF EATING TO GET ALL OF YOUR NUTRIENTS. BUT YOU CAN ALSO GET THEM FROM SUPPLEMENTS, SUCH AS THOSE MULTIVITAMIN AND MINERAL PILLS.

KAREN: SO WHICH ARE THE MOST IMPORTANT MINERALS FOR OUR BODIES?

ALYSON LEWIS: WELL, IRON IS CRUCIAL. IT SITS IN THE MIDDLE OF OUR RED BLOOD CELLS AND HELPS US TRANSPORT OXYGEN THROUGHOUT OUR

BODIES. PEOPLE WHO DON'T TAKE IN ENOUGH IRON MAY GET IRON DEFICIENCY ANEMIA. YOUNGER PEOPLE WHO DON'T TAKE IN ENOUGH IRON MAY GET ATTENTION DEFICIT DISORDER. CALCIUM IS ALSO A VERY IMPORTANT MINERAL. AS YOU MAY HAVE GUESSED, IT HELPS US WITH THE STRUCTURE OF OUR BONES AND TEETH. BUT A SMALL PERCENTAGE IS RESPONSIBLE FOR THE CONTRACTION OF MUSCLE. PEOPLE WHO DON'T TAKE IN ENOUGH CALCIUM MAY GET WEAKER BONES

AS THEY GET OLDER. THAT'S CALLED OSTEOPOROSIS.

KAREN: WHAT ABOUT POTASSIUM?

ALYSON LEWIS: POTASSIUM AND SODIUM ARE RESPONSIBLE FOR THE TRANSMISSION OF NERVE IMPULSES. AND MAGNESIUM HELPS US ABSORB CALCIUM BETTER.

KAREN: SHOULD I START TAKING MULTIVITAMINS TO MAKE SURE I GET ALL THE MINERALS I NEED?

ALYSON LEWIS: WELL, I STILL THINK IT'S BEST JUST TO FOLLOW A HEALTHY WAY OF EATING, SUCH AS OUTLINED BY THE CANADA FOOD GUIDE. AND THERE STILL NEEDS TO BE MORE RESEARCH BEFORE WE START RECOMMENDING MICRONUTRIENTS, SUCH AS COPPER AND SELENIUM. BUT EVEN THOSE ARE FOUND IN A HEALTHY DIET.

DARREN: WHEN WE GO FROM MENDELEEV'S TABLE TO THE MODERN TABLE, WE'RE SEEING THE DISCOVERIES AND REFINEMENTS THAT HAVE BEEN MADE OVER THE LAST HUNDRED YEARS OR SO. AND BOHR'S MODEL HELPS EXPLAIN WHY IT WORKS. THE PERIODIC TABLE PUTS CENTURIES OF THEORETICAL IDEAS AND EXPERIMENTAL DATA AT YOUR FINGERTIPS. AND IT ALLOWS YOU TO MAKE PREDICTIONS ABOUT THE ELEMENTS AND HOW THEY REACT WITH EACH OTHER.

SARAH: ON THE PERIODIC TABLE, METALS BECOME INCREASINGLY REACTIVE AS WE GO DOWN AND LEFT. NON-METALS BECOME INCREASINGLY REACTIVE AS WE GO UP AND RIGHT — EXCEPT AT THE EXTREME RIGHT, WHERE WE FIND THE NOBLE GASES.

DARREN: THE VALENCE ELECTRONS OF AN ELEMENT DETERMINE ITS CHEMICAL BEHAVIOR. YOU CAN FIND THE NUMBER OF VALENCE ELECTRONS FOR ANY REPRESENTATIVE ELEMENT BY THE POSITION OF ITS GROUP ON THE TABLE. NOBLE GASES HAVE FULL OUTER LEVELS. THINK OF THEM AS "ZERO." FOR METALS, COUNT FROM THE LEFT, ADDING ONE PER GROUP TO FIND OUT HOW MANY "EXTRA" VALENCE ELECTRONS THE METAL HAS TO GIVE AWAY. FOR NON-METALS, COUNT FROM RIGHT TO LEFT — NOBLE GASES BEING ZERO — TO FIND OUT THE NUMBER OF VALENCE ELECTRONS THE ELEMENT NEEDS TO FILL IN ITS OUTER ENERGY LEVEL.

LAUREEN: OKAY, WE'VE GOT TWO SETS OF REPRESENTATIVE ELEMENTS: MAGNESIUM AND OXYGEN, AND CARBON AND CHLORINE.

JULIEN: SO WHAT KIND OF REACTIONS CAN WE PREDICT FOR EACH SET BY USING THE PERIODIC TABLE OF ELEMENTS? FIRST, MAGNESIUM AND OXYGEN.

LAUREEN: MAGNESIUM IS A METALLIC ELEMENT. WHEN WE LOOK ON THE PERIODIC TABLE, WE FIND THAT IT'S SOMEWHAT REACTIVE.

JULIEN: AND COUNTING FROM THE LEFT SIDE, IT HAS TO GIVE AWAY TWO VALENCE ELECTRONS.

LAUREEN: WE'LL USE AN ENERGY-LEVEL DIAGRAM TO SHOW WHY. MAGNESIUM'S ATOMIC NUMBER IS 12. THAT MEANS IT HAS 12 PROTONS AND 12 ELECTRONS.

JULIEN: IT HAS TWO ELECTRONS ON ITS FIRST LEVEL. THE SECOND LEVEL HAS EIGHT. AND THE THIRD LEVEL HAS TWO. TWELVE ELECTRONS ALL TOGETHER.

LAUREEN: SO IT WILL NEED TO GET RID OF ITS TWO OUTER ELECTRONS.

JULIEN: RIGHT, TO BECOME STABLE.

LAUREEN: THEN THERE'S OXYGEN, WHICH IS A NON-METALLIC ELEMENT.

JULIEN: FROM ITS POSITION HERE ON THE TABLE, WE CAN SEE THAT IT'S PROBABLY QUITE REACTIVE. AND COUNTING FROM RIGHT TO LEFT, IT NEEDS TWO ELECTRONS.

LAUREEN: HERE'S WHY. OXYGEN'S ATOMIC NUMBER IS EIGHT. SO THAT MEANS IT HAS TWO ELECTRONS IN ITS FIRST LEVEL, AND SIX ELECTRONS IN ITS SECOND.

JULIEN: IT NEEDS TWO ELECTRONS TO FILL ITS OUTER LEVEL.

LAUREEN: SO WHEN THESE TWO ELEMENTS REACT, AN IONIC BOND WILL FORM.

JULIEN: ONE ATOM FROM EACH ELEMENT IS NEEDED FOR A STABLE STATE.

LAUREEN: MAGNESIUM OXIDE, MGO.

JULIEN: SECOND, THERE'S CARBON AND CHLORINE.

LAUREEN: CARBON IS ON THE NON-METAL SIDE OF THE TABLE. ITS POSITION HERE SHOWS IT HAS FOUR VALENCE ELECTRONS.

JULIEN: THE ENERGY-LEVEL DIAGRAM FOR THE CARBON

ATOM SHOWS US WHY.

LAUREEN: ITS ATOMIC NUMBER IS SIX. THAT MEANS IT HAS SIX ELECTRONS AND SIX PROTONS. ITS FIRST ENERGY LEVEL HAS TWO ELECTRONS, AND ITS SECOND HAS FOUR.

JULIEN: SO IT'LL SHARE FOUR OF ITS OWN ELECTRONS TO GET FOUR MORE AND FILL THE SECOND LEVEL.

LAUREEN: CHLORINE IS A NON-METAL, TOO. FROM ITS POSITION HERE ON THE TABLE, WE SEE THAT IT NEEDS ONE VALENCE ELECTRON TO FILL ITS OUTER ENERGY LEVEL. ITS ATOMIC NUMBER IS 17. WHICH MEANS IT HAS TWO ELECTRONS IN ITS FIRST LEVEL, EIGHT IN ITS SECOND, AND SEVEN IN ITS THIRD. THAT'S 17.

JULIEN: SO IT'LL SHARE ONE OF ITS OWN ELECTRONS TO GET ONE ELECTRON BACK AND FILL THE THIRD LEVEL.

LAUREEN: WE PREDICT A COVALENT BOND.

JULIEN: WITH EVERY FOUR ATOMS OF CHLORINE BONDING WITH EVERY ONE ATOM OF CARBON.

LAUREEN: THAT SHOULD GIVE US CARBON TETRACHLORIDE, CCL₄, A MOLECULAR COMPOUND.

SARAH: WHICH IS A NON-POLAR SOLVENT USED IN PREPARING OTHER CARBON COMPOUNDS. NICE JOB WITH YOUR CHEMICAL PREDICTIONS.

JULIEN: IF YOU APPLY THE RULES, IT ISN'T TOO HARD.

SARAH: THAT'S TRUE. BUT IT'S IMPORTANT TO RECOGNIZE THAT WE'VE BEEN APPLYING THE SIMPLEST RULES OF CHEMICAL BEHAVIOR.

LAUREEN: SO THERE ARE OTHER POSSIBILITIES?

SARAH: ABSOLUTELY! CHEMICAL REACTIONS CAN BE VERY COMPLEX. MANY ELEMENTS, UNDER THE APPROPRIATE CONDITIONS, CAN COMBINE IN DIFFERENT PROPORTIONS.

JULIEN: LIKE WHAT?

SARAH: FOR EXAMPLE, CARBON PLUS OXYGEN CAN REACT TO FORM CARBON DIOXIDE...OR CARBON MONOXIDE. CARBON CAN ALSO COMBINE TO FORM THE MOST FANTASTIC AND COMPLEX ORGANIC MOLECULES, FROM SUCROSE...TO GASOLINE. AND HYDROGEN BREAKS ALL THE RULES. THE WAY IT REACTS DEPENDS ON THE CHEMICAL SITUATION. IT CAN FORM POSITIVE IONS, NEGATIVE IONS, NEUTRAL ATOMS, OR

NEUTRAL MOLECULES.

JULIEN: SO THE SIMPLE RULES THAT WE USED ARE CORRECT.

LAUREEN: BUT THEY ONLY TAKE US SO FAR.

SARAH: THAT'S TRUE! THE RULES OF CHEMICAL BONDING ARE USEFUL, BUT THEY'RE NEVER REALLY ABSOLUTE. THEY'RE THE BEST EXPLANATIONS WE HAVE FOR WHAT WE OBSERVE.

MAY YEW: THE WHEELS ARE REALLY LIGHT. THEY WANT TO MAKE THE WHEELS NOT ONLY LIGHT, BUT THEY WANT TO MAKE THEM STRONG, AS WELL. SO YOU WON'T SEE ANY STEEL WHEELS. STEEL IS VERY HEAVY. MOST OF THE TIME THEY'LL GO TO AN ALLOY WHEEL, WHICH IS WHAT THIS WHEEL IS RIGHT HERE. IT'S NOT ONLY LIGHTER, BUT IT'S MUCH STRONGER AND IT CAN BE TRUED. SO WE CAN STRAIGHTEN THE WHEEL, MAKE IT ROUND AGAIN. WHEREAS THE STEEL WHEEL, YOU JUST HAVE TO THROW IT AWAY. IT JUST CANNOT BE STRAIGHTENED ANYMORE. BUT THEY'RE ALSO MAKING CARBON FIBER WHEELS, USING THEM FOR RACE WHEELS. SO THEY'RE VERY, VERY LIGHTWEIGHT. YOU WOULDN'T USE THIS EVERY DAY, BECAUSE IT WILL GO THROUGH A LOT. BUT YOU CAN USE THEM FOR A RACE WHEEL, BECAUSE THEY'RE LIGHT AND THEY'RE VERY STRONG, AS WELL.

DARREN: ARE THEY EXPENSIVE?

MAY YEW: THEY ARE. THIS WHEEL RIGHT HERE IS WORTH ABOUT \$700.00.

DARREN: NATURE OFTEN CREATES PUZZLES FOR US TO FIGURE OUT. BOHR'S MODEL OF THE ATOM AND THE MODERN PERIODIC TABLE HELP US EXPLAIN A LOT ABOUT THE STRUCTURE AND BEHAVIOR OF THE ELEMENTS. BUT OUR THEORETICAL MODELS ARE BASED ON OBSERVATION. AND OFTEN, WE MUST ADJUST OUR THEORIES...TO FIT THE FACTS. IT'S SIMPLY SCIENCE!