SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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Student Materials

Learning Sequence Item:

1041

Periodicity of the Elements

January 1997
Adapted by: Gary Freebury and George Miller

Contents

This micro-unit was adapted by **Gary Freebury** (Flathead High School, Kalispell, Mont.) and **George Miller** (University of California, Irvine)

Student Sheet

Science as Inquiry

Periodicity of Elements

How can we discover patterns?

Objective:

In 1869, Dimitri Mendeleev introduced a periodic table that had only about two-thirds of the naturally occurring elements known today. However, he was able to predict the properties of those missing elements and to leave space for many of these elements on his periodic table. Without referring to the periodic table, you will create your own periodic table based on the properties of the elements.

Procedure:

Your team will be assigned a physical or chemical property common to the elements, such as density or boiling point. You will use this property for both Activities 1 and 2.

Using the attached table of values, list the 88 elements in some sort of logical order based on their values for the assigned property. For example, for the property boiling point, you might organize elements by placing them in increasing order. When you have listed all the elements, write the symbol of each element and its value for the property on a sheet from a Post-it® pad and post these notes on a wall or chalkboard along with those of the other lab groups.

When all of the properties are posted, look for a repeating pattern that can be found in all the properties of the elements. Some teams will have missing values for their property for certain elements. Try to decide where these missing values should be posted from the pattern that your class has developed.

Questions:

1. Compare your periodic table to the standard periodic table. How does your periodic table differ?

2. How can you determine the physical state of an element (gas, liquid, or solid) at room temperature from the values in the periodic table? How many elements are there in each form?

3. The periodic table shows the state in which elements exist at room temperature. How many elements would exist in each form (solid, liquid, or gas) on a planet where room temperature is 100 ^{o}C?

Element	**Mass** (amu)	**Boiling Point** (K)	**Melting Point** (K)	**Density** (g/cc)	**Atomic Radii** (angstroms)	**Ionization Potential** (electron voltage)	**Specific Heat** (J/g/K)	**Electronegativity** (Pauling's scale)	**Heat of Fusion** (kJ/mol)
Aluminum	26.98	2740	933.5	2.7	1.82	5.986	0.9	1.61	10.7
Antimony	121.8	1860	903.91	6.69	1.53	8.641	0.207	2.05	19.83
Argon	39.95	87.45	83.95	0.001784	0.88	15.759	0.52	—	1.188
Arsenic	74.92	876 (subl.)	1090 (28 atm)	5.78	1.33	9.81	0.33	2.18	27.7
Astatine	210	610	575	—	1.43	—	—	2.2	12
Barium	137.3	2078	1002	3.59	2.78	5.212	0.204	0.89	8.01
Beryllium	9.01	3243	1560	1.85	1.4	9.322	1.825	1.57	11.71
Bismuth	209.0	1837	544.59	9.75	1.63	7.289	0.122	2.02	11
Boron	10.81	4275	2365	2.34	1.17	8.298	1.026	2.04	22.6
Bromine	79.9	331.85	265.95	3.12	1.12	11.814	0.226	2.96	5.286
Cadmium	112.4	1040	594.26	8.65	1.71	8.993	0.232	1.69	6.07
Calcium	40.08	1757	1112	1.55	2.23	6.113	0.647	1	8.53
Carbon	12.01	5100	3825	2.26	0.91	11.26	0.709	2.55	—
Cerium	140.1	3715	1071	6.77	2.7	5.47	0.19	1.12	9.2
Cesium	132.9	944	301.54	1.87	3.34	3.894	0.24	0.79	2.092
Chlorine	35.45	239.18	172.17	0.003214	0.97	12.967	0.48	3.16	3.21
Chromium	52	2945	2130	7.19	1.85	6.766	0.449	1.66	20
Cobalt	58.93	3143	1768	8.9	1.67	7.86	0.421	1.88	16.19
Copper	63.55	2840	1356.6	8.96	1.57	7.726	0.385	1.9	13.14
Dysprosium	162.5	2840	1685	8.55	2.49	5.93	0.173	1.22	11.96

Element	Mass (amu)	Boiling Point (K)	Melting Point (K)	Density (g/cc)	Atomic Radii (angstroms)	Ionization Potential (electron voltage)	Specific Heat (J/g/K)	Electronegativity (Pauling's scale)	Heat of Fusion (kJ/mol)
Erbium	167.3	3140	1802	9.07	2.45	6.101	0.168	1.24	17.15
Europium	152	1800	1095	5.24	2.56	5.67	0.182	1.2	10.46
Fluorine	19	85	53.55	0.001696	0.57	17.422	0.824	3.98	0.26
Francium	223	950	300	—	—	—	—	0.7	2.1
Gadolinium	157.3	3545	1585	7.9	2.54	6.15	0.236	1.2	15.48
Galium	69.72	2478	302.92	5.91	1.81	5.999	0.371	1.81	5.59
Germanium	72.61	3107	1211.5	5.32	1.52	7.899	0.32	2.01	31.8
Gold	197.0	3130	11337.58	19.3	1.79	9.225	0.128	2.54	12.36
Hafnium	178.5	4875	2504	13.31	2.16	6.65	0.14	1.3	21.76
Helium	4.0	4.216	0.95 (26 atm)	0.0001785	0.49	24.587	5.193	—	0.021
Homium	164.9	2968	1747	8.8	2.47	6.02	0.165	1.23	17.15
Hydrogen	1.01	20.28	13.81	0.0000899	0.79	13.598	14.304	2.1	0.0585
Indium	114.8	2350	429.78	7.31	2	5.786	0.233	1.78	3.26
Iodine	126.9	457.5	386.7	4.93	1.32	10.451	0.145	2.66	7.76
Iridium	192.2	4700	2720	22.6	1.87	9.1	0.13	2.2	26.36
Iron	55.85	3023	1808	7.874	1.72	7.87	0.449	1.83	13.8
Krypton	83.8	120.85	116	0.00375	1.03	13.999	0.248	—	1.638
Lathanum	138.9	3737	1191	6.15	2.74	5.58	0.19	1.1	11.3
Lead	207.2	2023	600.65	11.35	1.81	7.416	0.129	2.33	4.77
Lithium	6.94	1615	453.7	0.53	2.05	5.382	3.582	0.98	3

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Lutedium	175.0	3668	1936	9.84	2.25	5.43	0.15	1.27	18.6
Magnesium	24.3	1380	922	1.74	1.72	7.646	1.02	1.31	8.95
Manganese	54.94	2235	1518	7.44	1.79	7.435	0.48	1.55	1464
Mercury	200.6	629.88	234.31	13.55	1.76	10.437	0.14	2	2.292
Molybdenum	95.94	4912	2896	10.22	2.01	7.099	0.25	2.16	36
Neodymium	144.2	3347	1294	7.01	2.64	5.49	0.19	1.14	10.88
Neon	20.18	27.1	24.55	0.0009	0.51	21.564	1.03	—	0.34
Nickel	58.69	3005	1726	8.9	1.62	7.635	0.444	1.91	17.2
Nioblum	92.91	5015	2742	8.57	2.08	6.88	0.265	1.6	26.9
Nitrogen	14.01	77.344	63.15	0.001251	0.75	14.534	1.042	3.04	0.36
Osmium	190.2	5300	3300	22.6	1.92	8.7	0.13	2.2	29.29
Oxygen	16	90.188	54.8	0.001429	0.65	13.618	0.92	3.44	0.222
Palladium	106.4	3240	1825	12	1.79	8.34	0.244	2.2	16.74
Phosphorous	30.97	553	317.3	1.82	1.23	10.486	0.769	2.19	0.63
Platinum	195.1	4100	2042.1	21.45	1.83	9	0.13	2.28	19.66
Polonium	209	—	527	9.3	1.53	8.42	—	2	13
Potassium	39.1	1033	336.8	0.86	2.77	4.341	0.757	0.82	2.33
Praseodymium	140.9	3785	1204	6.77	2.67	5.42	0.193	1.13	10.04
Promethium	145	3273	1315	7.22	2.62	5.55	—	1.13	—
Radium	226	1413	973	5	—	5.279	0.094	0.89	8.37

Element	Mass (amu)	Boiling Point (K)	Melting Point (K)	Density (g/cc)	Atomic Radii (angstroms)	Ionization Potential (electron voltage)	Specific Heat (J/g/K)	Electronegativity (Pauling's scale)	Heat of Fusion (kJ/mol)
Radon	222	211.4	202	9.73	1.34	10.748	0.094	—	2.9
Rhenium	186.2	5870	3455	21	1.97	7.88	0.137	1.9	33.05
Rhodium	102.9	3970	2236	12.41	1.83	7.46	0.242	2.28	21.76
Rubidium	85.47	961	312.63	1.532	2.98	4.177	0.363	0.82	2.34
Ruthenium	101.1	4425	2610	12.37	1.89	7.37	0.238	2.2	25.52
Samarium	150.4	2067	1347	7.52	2.59	5.63	0.197	1.17	11.09
Scantium	44.96	3109	1814	2.99	2.09	6.54	0.568	1.36	16.11
Selenium	78.96	958	494	4.79	1.22	9.752	0.32	2.55	5.54
Silicon	28.09	2630	1683	2.33	1.46	8.151	0.7	1.9	50.2
Silver	107.9	2436	1235.08	10.5	1.75	7.576	0.235	1.93	11.3
Sodium	22.99	1156	371	0.97	2.23	5.139	1.23	0.93	2.601
Strontium	87.62	1655	1042	2.54	2.45	5.695	0.3	0.95	8.2
Sulfur	32.07	717.82	392.2	2.07	1.09	10.36	0.71	2.58	1.73
Tantalum	180.9	5730	3293	16.65	2.09	7.89	0.14	1.5	36
Technetium	98	4538	2477	11.5	1.95	7.28	0.24	1.9	23
Tellurium	127.6	1261	722.72	6.24	1.42	9.009	0.202	2.1	17.49
Terbium	158.9	3500	1629	8.23	2.51	5.86	0.18	1.1	—
Thallium	204.4	1746	577	11.85	2.08	6.108	0.129	2.04	4.27
Thullum	158.9	2223	1818	9.32	2.42	6.184	0.16	1.25	16.8
Tin	118.7	2876	505.12	7.31	1.72	7.344	0.228	1.96	7.2

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Titanium	47.88	3560	1935	4.54	2	6.82	0.523	1.54	18.6
Tungsten	183.9	5825	3695	19.3	2.02	7.98	0.13	2.36	35.4
Vanadium	50.94	3650	2163	6.11	1.92	6.74	0.489	1.63	22.8
Xenon	131.3	165.1	161.39	0.0059	1.24	12.13	0.158	2.6	2.3
Ytterbium	173	1469	1092	6.97	2.4	6.254	0.155	1.1	7.7
Yttrium	88.91	3611	1795	4.47	2.27	6.38	0.3	1.22	17.15
Zinc	65.39	1180	692.73	7.13	1.53	9.394	0.388	1.65	7.38
Zirconium	91.22	4682	2128	6.51	2.16	6.84	0.278	1.33	21

Student Sheet

Science as Inquiry

Graphing the Elements

What can graphs reveal about the patterns of elements?

Overview:

In the previous activity, you developed your periodic table by looking for a repeating pattern among the properties. In this activity you will see if periodicity is more obvious when you graph a property in one dimension or as a three-dimensional model.

Procedure:

Using your table of values from Activity 1 and other provided sources of information, tabulate the values for your assigned property by atomic number. Now construct a graph of the data, with atomic numbers on the x-axis and values for the assigned property on the y-axis. To better visualize periodicity use colored pencils to define the different periods.

Next, using the materials provided, make a three-dimensional model of the property in the form of the periodic table. If you have been given well plates, tape the two plates together in such a manner that you have 24 wells across the top and 8 down the side. You will use 18 wells across for columns and 6 down for periods. This will allow you to place the lanthanides (rare earth elements) at the bottom of the distribution as they are usually represented on the periodic table.

Cut soda straws in lengths proportional to the units of the property you are graphing and insert them in the wells. Remember to take into account the depth of the wells so that you do not cut straws too short. If you have a variety of colored straws you may be creative in designing your model.

Similarly, if using Styrofoam® or plywood, scale the dowels, skewers, or wire to be proportional to the units of your assigned property and arrange them in the holes as on the periodic table. Again, you could be creative and use a different color for each column or period.

Questions:

1. Define the property you were assigned and explain how you would use it to look for a repeating pattern among the properties of the elements.

2. Predict the missing values missing on your graph. Use references to check the accuracy of your predictions.

3. Based on your graph and three-dimensional model, what value would you assign to a new element with an atomic number of 113?

4. The Russian chemist Dimitri Mendeleev is given credit for developing the periodic table in 1869. Shortly after, Julius Meyer, a German physicist, published his own periodic table, which was similar to Mendeleev's. Neither of these scientists was aware all of the elements and yet each was able to develop the table. What complete family of elements were they missing, and why?

Student Sheet

5. Since early chemists used atomic mass (called atomic weight at that time) rather than atomic number as the basis for the periodic table, there were at least six elements that didn't seem to fit in the proper places. It was assumed that their masses had been measured incorrectly. In fact, the masses were correct and there was another explanation for the positions of these elements in the table. Scientists can be right for the wrong reason! What were the six elements?