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| **Title** | **Sensors in Chemistry** |
| **Introduction** | Thermal energy can drastically affect the properties of a gas. Have you ever wondered why a balloon in a hot car will expand? Or why air has to be released from car tires in the summer and added in the winter? The reason for these physical phenomena can be explained using the gas laws.  Gas Pressure and volume are affected by temperature changes.  These are demonstrated by Charles’ Law, which states that with constant pressure, volume increases as temperature increases, and Gay-Lussac’s Law, which states that with constant volume, pressure increases as temperature increases.  In Boyle’s Law, Pressure and volume are inversely correlated, which means as volume increases pressure will decrease and vice versa.  Furthermore Avogadro’s Law states that with constant pressure and temperature, volume and the molar amount of a gas are directly related, when one increases so will the other and vice versa. Combining all of these laws and using some simple algebra we can show the ideal gas law.    “An ideal gas is defined as one in which all collisions between atoms or molecules are perfectly elastic and in which there are no intermolecular attractive forces. One can visualize it as a collection of perfectly hard spheres which collide but which otherwise do not interact with each other. In such a gas, all the [internal energy](http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/inteng.html#c2) is in the form of kinetic energy and any change in internal energy is accompanied by a change in [temperature](http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/temper.html#c1).” Carl Nave, HyperPhysics, (2012).  Ideal gas law: PV=nRT, where:  n = number of [moles](http://hyperphysics.phy-astr.gsu.edu/hbase/kinetic/idegas.html#c4)  R = universal gas constant = 8.3145 L\*kPa/mol\*K  P= pressure (kPa)  V= volume (L)  T= Temperature (Kelvin)  In this lesson students will use sensor technology to learn about the ideal gas law.  Students will collect data, complete analysis of data, and create an ideal gas law problem using data collected. |
| **Real Science Application** | Sensors are used for multiple purposes in many areas of science including health and environmental monitoring.  Examples of health monitoring include heart rate, breathing rate, oxygenation rate, seizure activity, and brain activity.  Examples of environmental monitoring include pollution levels, toxicity of pollutants and effect on surrounding species, atmospheric gases, and location of pollutants.  The use of sensors in wearable devices is extensive for heart rate monitoring, step counters, and tracking exercise. Many brands exist such as FitBit, Garmin, and Gear Fit. |

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| **Curriculum Alignment** | |  |  |  |  | | --- | --- | --- | --- | | Content Area | Grade Level | NC Essential Standards | Next Generation Science Standards | | Chemistry | 10-12 | Chm.2.1.5  Explain the relationships between pressure, temperature, volume, and quantity of gas both qualitative and quantitative. | PS3.D  Energy in chemical processes and everyday life. | | Chemistry | 10-12 | Chm.2.2.4  Use mole ratios from the balanced equation to calculate the quantity of one substance in a reaction given the quantity of another substance in the reaction. (given moles, particles, mass, or volume and ending with moles, particles, mass, or volume of the desired substance) | PS3.D  Energy in chemical processes and everyday life. | |
| **Learning Outcomes** | Students will investigate how temperature affects the Ideal Gas Law.  Students will explain how variables affect experiments.  Students will analyze and graph sensor data. |
| **Time Required and Location** | 90 minute class period in classroom for introduction to temperature, sensors, ideal gas law on day 1.  90 minute class period to connect sensors and collect data on day 2. (Data can be collected in the classroom or other locations if desired).  90 minute class period to analyze and graph data, then discuss results and implications by completing the analysis questions on day 3.  For 45 minutes classes the lesson may take up to 6 days. |

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| **Materials Needed** | Teacher List   * Ideal Gas Law presentation (Appendix A) * Sensor Use presentation (Appendix B)   Student List   * Student worksheet ,1 per student (Appendix C) * Mobile device ,1 per student or pair * Pencil * TI Sensor Tags, 1 per student or pair |
| **Safety** | Keep the TI Sensor Tags in their plastic case with rubber protective cover. Opening the device could lead to damage of the circuit board. Use the school’s wifi to ensure inappropriate sites are blocked on mobile devices. |
| **Participant Prior Knowledge** | Students should be familiar with temperature and how it is measured. Students should know about the conservation of energy. Teachers should be familiar with temperature and how it is measured. Students should know about the conservation of energy. |
| **Facilitator Preparations** | * Become familiar with the [TI Sensor](http://www.ti.com/sensortag) [Tag](http://www.ti.com/sitesearch/docs/universalsearch.tsp?searchTerm=sensortag#linkId=2), mobile app, and uploading data to the cloud from the app. * Understand limits of sensor tags, such as extreme temperatures, ground temperature versus air, and sensitivity. * Review examples of [troubleshooting](http://e2e.ti.com/support/sensor). * Find a space to collect data (classroom, outside, main lobby, media center, etc.) * Make copies of student worksheet and rubrics. * Access presentations and download if necessary for use in class. |
| **Activities** | **Day 1:**  Introduction to Gas Laws presentation, conduct a lecture and class discussion while students take notes [40 minutes]  Direct the students to privately writing down statements about what they already know about temperature, its measurement, and why they think it is important to chemistry.  [10 minutes]  Open class discussion by asking the students to define the word “temperature”.  Be sure to define temperature as the measurement of the kinetic energy produced by the motion of molecules and their collisions.  More movement leads to increased collisions increasing kinetic energy and thus temperature.  Make sure different measurements are included, such as Kelvin, Celsius, and Fahrenheit.  [10 minutes]  Sensor Use presentation, conduct while students take notes.[20 minutes]  Final student questions and clean up [10 minutes]  **Day 2:**  Discuss rubric with students.  Project the rubric or hand out printed copies of the rubric.  Allow students time to look over the instructions.  Ask students to explain the assignment instructions sequentially.  Ask students to use the rubric to identify the elements of an “A” paper. [25 minutes]  Practice connecting devices before collecting data on day 3.  Pass out sensor tags to students. Students will use notes from the Sensor Tag Usage presentation to connect their device to the mobile device.  Students will need to add tags in a sequence, one group at a time to ensure they are accessing the data for their sensor. [40 minutes]  Trouble-shoot any connection issues, such as no power, dead battery, or wrong tag connected. [15  minutes]  Final  student questions and clean up [10 minutes]  **Day 3:**  Pass out sensor tags and data sheets to students.  Let students collect data, at least 10 temperature data points, in a designated area. If students finish early, they can begin the analysis questions. [45  minutes max]  Provide a quiet class environment for students to begin planning their response.  Circulate in the classroom to answer any questions that arise and to support strong planning before data analysis. [40 minutes]  Collection of student data sheet and analysis questions. [5 minutes] |
| **Assessment** | Rubrics will be used for assessing (1) the notes and data collected during research (2) analysis questions, and (3) the graphs of the data.  Knowledge of sensors and their applications to standards will be assessed by formative assessments (listening to group talk, write to learn exercises, etc.) and by questions included on quizzes (Appendix D).  See Appendix E for the following rubrics  1.  Rubric for data table  2.  Rubric for analysis questions  3.  Rubric for graphs. |

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| **Critical Vocabulary** | Conservation of energy: energy cannot be created nor destroyed; it can only change forms.  Energy: capacity to do work or to produce heat.  Kinetic energy: energy that an object has due to its motion.  Mole: the amount of a substance that contains 6.02 × 1023 representative particles of that substance.  Pressure: applied force per unit area on a surface.  Temperature: measure of the average kinetic energy of the particles in matter.  Volume: measure of the space occupied by a sample of matter. |
| **Community Engagement** | The EPA has facilities in the Research Triangle Park and at the University of North Carolina- Chapel Hill campus. They provide outreach to schools, through the [RTP Speakers Bureau](https://www.epa.gov/rtp-speakers-bureau) |
| **Extension Activities** | Researchers at the EPA are studying air pollution using sensors for specific chemicals, such as ozone, oxides of nitrogen, particulate matter, VOCs, lead, and sulfur dioxide. They are observing the physiological responses to pollutants. This has helped develop clean air standards.  A number of interesting issues are related to this research, for example:  • What pollutants are the most dangerous and where do they exist?  • Do you think income level correlates to exposure to pollution?  • Would you participate in the research at the EPA?  • Are certain groups more sensitive to pollution? |

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| **Modifications** | Create a small group of students who struggle with comprehension and, particularly, have a limited vocabulary. Guide a read-aloud session, discussing small sections of reading at a time to aid comprehension and talking through decoding of difficult words. If it is not possible to oversee this in this manner, a student assistant could be used.  Many classes will have a student proficient in English and another language. Ask these students to volunteer as translators for English language learners. This is especially helpful in lab situations.  Ask students who understand the concepts and technology to act as class experts. They can help struggling students, explain concepts in another way, and help with data collect and graphing. This can be a great way to involve AIG students.  If TI Sensor Tags are not available, most smartphones have sensors that can be utilized to take pressure and temperature readings. Also, weather data can be used. Most schools act as local weather stations and should have measurements near the building. |
| **Alternative Assessments** | Modified assignments with less analysis questions and graph one piece of data per graph, instead of multiple sources. Students could also use at least 5 data points, instead of 10. This would still provide a graphical representation of their data. |
| **References** | NC Chemistry Standards  <http://www.ncpublicschools.org/docs/acre/standards/support-tools/unpacking/science/chemistry.pdf>  [A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas ( 2012 )](http://www.nap.edu/catalog.php?record_id=13165)  <http://www.nap.edu/openbook.php?record_id=13165&page=128>  TI Sensor Tag Information  <http://www.ti.com/ww/en/wireless_connectivity/sensortag2015/?INTC=SensorTag&HQS=sensortag>  <http://www.ti.com/sitesearch/docs/universalsearch.tsp?searchTerm=sensortag#linkId=2>  TI Sensor Tag User Guide  <http://processors.wiki.ti.com/index.php/CC2650_SensorTag_User's_Guide>  Ideal Gas Law  <http://hyperphysics.phy-astr.gsu.edu/hbase/kinetic/idegas.html#c1>  EPA RTP Speakers Bureau  <https://www.epa.gov/rtp-speakers-bureau>  [CK-12 Chemistry-Intermediate textbook](https://drive.google.com/a/wcpss.net/file/d/0B6J2zVcy0_opTlV1UXFXNDNwRTA/view) |
| **Appendices** | Appendix A: Ideal Gas Law Presentation  Appendix B: Sensor Use Presentation  Appendix C: Student Worksheet  Appendix D: Ideal Gas Law Quiz  Appendix E: Rubric for data collection, analysis questions, and graphs  Appendix F: Formal Writing Guide  Appendix G: Blank Lab Report Template  Appendix H: Sample spreadsheet with formulas  Appendix I: Sample spreadsheet with example data and graphs  Appendix J: Rubric for optional formal lab report  Appendix K: Sample Rubric for optional formal lab report |
| **Supplemental Information** | [EPA at UNC-Chapel Hill](https://www.epa.gov/aboutepa/about-national-health-and-environmental-effects-research-laboratory-nheerl#ephd)  [EPA in the RTP](https://www.epa.gov/aboutepa/about-epas-campus-research-triangle-park-rtp-north-carolina#tab-3) |
| **Comments** | This lesson is written for Honors Chemistry.  Additional time will need to be provided in academic classes.  The teacher may choose to assign a lab report for the activity, utilizing the data sheet and analysis questions to write the report.  Teacher should provide an additional class period for students to outline their reports and ask any clarifying questions.  An explanation of formal writing used in lab reports, provided to first year NC State chemistry students, can be found in Appendix F.  A blank formal lab template can be found in Appendix G.  A spread sheet can be used to create formulas to convert units.  A sample data sheet with formulas can be found in Appendix H, and a sample data sheet completed with data can be found in Appendix I.  A rubric for the lab report is included in Appendix J, with a sample rubric in Appendix K. |
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