Unit Plan – Grade 11: Gases and Atmospheric Chemistry

Melissa Provost, Andrea Wylie & Bejay Prosser

Instructor: Marcel Dufresne

Class: CURS 4120U – I/S Chemistry

Date: Thursday, February 19, 2009
<table>
<thead>
<tr>
<th>Order of Units</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Matter, Chemical Trends, and Chemical Bonding</td>
<td>In this unit, you will be able to • show that you understand the relationship among periodic trends, types of chemical bonding, and the properties of ionic and molecular compounds; • carry out laboratory studies of chemical reactions, and analyze chemical reactions in terms of the type of reaction and the reactivity of starting materials; • use appropriate symbols and formulas to represent the structure and bonding of chemical substances; • describe how an understanding of matter and its properties can lead to the production of useful substances and new technologies.</td>
</tr>
<tr>
<td>2</td>
<td>Chemical Reactions</td>
<td>In this unit, you will be able to • analyse chemical reactions used in a variety of applications, and assess their impact on society and the environment; • investigate different types of chemical reactions; • demonstrate an understanding of the different types of chemical reactions.</td>
</tr>
<tr>
<td>3</td>
<td>Quantities in Chemical Reactions (Solids)</td>
<td>In this unit, you will be able to • use the mole concept in the analysis of chemical systems; • carry out experiments and complete calculations based on quantitative relationships in balanced chemical reactions; • develop an awareness of the importance of quantitative chemical relationships in the home and in industry.</td>
</tr>
<tr>
<td>4</td>
<td>Solutions and Solubility (Liquids)</td>
<td>In this unit, you will be able to • understand the properties of solutions, the concept of concentration, and the importance of water as a solvent; • prepare, analyze, and react solutions using qualitative and quantitative methods; • relate the scientific knowledge of solutions and solubility to a variety of technological, societal, and environmental examples, including water quality</td>
</tr>
<tr>
<td>5</td>
<td>Gases and Atmospheric Chemistry (Gases)</td>
<td>In this unit, you will be able to • demonstrate an understanding of the laws that govern the behaviour of gases; • investigate through experimentation the relationships among the pressure, volume, and temperature of a gas and solve problems involving amount of substance in moles, molar masses and volumes, and the gas laws; • describe how knowledge of gases has helped to advance technology and how such technological advances have led to a better understanding of environmental phenomena and issues.</td>
</tr>
</tbody>
</table>
**Unit Objective:** The objective is to teach students the necessary skills to become good problem solvers and critical thinkers. They will develop other skills including, organization, time management, study skills etc, through a variety of teaching strategies. This will be done using Gases and Atmospheric Chemistry as the content for teaching the previously mentioned skills, so that the students will have a working knowledge of the chemistry of gases.

<table>
<thead>
<tr>
<th>Textbook Chapter</th>
<th>Expectation</th>
<th>Lesson Outline</th>
<th>Assessment &amp; Evaluation</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Chapters</td>
<td>F2.1 use appropriate terminology related to gases and atmospheric chemistry, including, but not limited to: standard temperature, standard pressure, molar volume, and ideal gas [C]</td>
<td>N/A</td>
<td>N/A</td>
<td>1 Lesson (75 min)</td>
</tr>
</tbody>
</table>
| 9.1 States of Matter | F3.2 describe the different states of matter, and explain their differences in terms of the forces between atoms, molecules, and ions | **Hook:** Can you smell that? (Diffusion of ammonia gas through the classroom)  
**Lesson/Discussion:**  
Different states of matter  
- Class discussion since this material is review for the students  
- The teacher will probe for the use of specific terms such as ionic, covalent and intermolecular forces  
**Video** “Kinetic Theory, Atmospheric Pressure and Gas Pressure”  
- Kinetic-Molecular Theory  
- Pressure  
Explaining the gas state  
Graham’s Law of diffusion  
**Activity:** Graham’s Law of Diffusion Lab [http://www.gpb.org/chemistry-physics/chemistry/903](http://www.gpb.org/chemistry-physics/chemistry/903) | **Assessment:** Students will be assessed throughout the class discussion based on their contribution of ideas and participation. As students work on tasks the teacher will wander around the room to assess the students’ progress (i.e. when students are calculating the conversion of pressure etc).  
**Evaluation:** In addition students will be assessed during the Graham’s Law of Diffusion lab. At the end of the class students will submit their lab write up. The teacher will evaluate the lab write ups and the marks will contribute to their final mark. | 1 lesson |
| 9.2 Gas Laws | F3.5 explain Dalton’s law of partial pressures, Boyle’s law, Charles’s law, Gay-Lussac’s law, the combined gas law, and the ideal gas law |
| 9.3 Compressed Gasses |  |
|  | F2.2 determine, through inquiry, the quantitative and graphical relationships between the pressure, volume, and temperature of a gas [PR, AI] |
|  | F2.3 solve quantitative problems by performing calculations based on Boyle’s law, Charles’s law, Gay-Lussac’s law, the combined gas law, Dalton’s law of partial pressures, and the ideal gas law [AI] |

**Lesson 1:** See Boyles and Charles’ law lesson plan.

**Lesson 2:**
**Hook:** Hot and Cold Bouncers
- Chill 1 basketball overnight in a freezer (remove right before demo to avoid time to heat up), warm another basketball in a hot water bath. Have student volunteers assist by taping a measuring tape to the wall. Have the class write hypotheses about temperature-bounciness relationship. Measure the height of each ball separately, complete 3 trials. Have the class explain the observations using the notion of pressure and temperature. Connect with Gay-Lussac’s Gas Law.

**Lesson/Discussion:**
Submit Homework

The relationship between pressure and Temperature: Gay-Lussac’s Law
- Example questions
- Discuss the “Hot and Cold Bouncers” activity that was conducted at the beginning of the class

Video “More About the Behaviour of Gases”
- Combined Gas Law

Continued discussion on combined gas law
- Example questions

**Lesson 1:** See Boyles and Charles’ law lesson plan.

**Lesson 2:**
**Assessment**
Students will be assessed throughout the lesson based on their contribution to the class discussions. In addition, the teacher will walk around the class as students work through the practice problems (at the end of both Gay-Lussac’s and the combined gas law discussion). The teacher will be assessing each student’s progress and understanding of the material taught in this and the previous lessons. Today’s lesson includes a brief activity that will be answered at the end of the lesson. Students will be assessed based on their contribution to solving the problem.

**Evaluation**
Students will be required to complete the homework handout that includes Gay-Lussac’s and the Combined gas law questions. Students will be submitting this small exercise for evaluation purposes which is due at the end of class. By having the student submit it for marks, students will receive full feedback on their work and have an example of what to expect for the test and exam.

| 4 lessons | 3 Teaching 1 Lab |
### Activity:
Assignment Handout (similar to the previous class assignment)
- Practice questions
  - Gay-Lussac’s Law
  - the combined gas law

### Homework:
- Pre-lab questions due before they can participate in the lab next class.

### Lesson 3: Lab day
**Hook:** Demonstration of lab
- The teacher will go over what is expected of the students during this activity and what they need to steps to complete it.

**Activity:**
[http://www.miracosta.edu/home/dlr/100exp.htm](http://www.miracosta.edu/home/dlr/100exp.htm) - **Experiment 11: Gas Laws Lab**
- Students will be given class time at the end of the lab to work on their graphs and write up.

Students will receive their assignments back from the previous classes (Boyles, Charles’, Gay-Lussac’s and Combine gas law questions).

### Lesson 4: Compressed Gases
**Hook:** Jen’s Hook
- Aerosol can decrease in temperature as it is sprayed.

---

**Lesson 3: Lab Day**
**Assessment**
As students are participating in the lab, the teacher will be walking around the room to assess students’ progress and participation.

**Evaluation**
Students are required to submit their lab write up with graphs at the end of the class. If students do not finish by the end of the class they will be allowed take it home and submit it at the beginning of the next class. The lab write up also includes the pre-lab questions that were due at the beginning of this class. If students have not finished it, they will not participate until it is completely finished.

**Lesson 4: Compressed Gases**
**Assessment**
Students will be assessed throughout the class while they are working independently or participating in a class discussion. As students
<table>
<thead>
<tr>
<th><strong>Lesson/Discussion:</strong></th>
<th>work on the assigned questions, the teacher will be walking around the class to assist students when needed. During this time, students will be assessed on their participation.</th>
</tr>
</thead>
</table>
| Take up the assigned Questions go over questions students had difficulty with from the 1st and 2nd Gas Law lessons. (Questions assigned for Boyles, Charles’, Gay-Lussac’s and Combined Gas Laws). | **Evaluation**
Students will be completing a “POP” quiz during this class. The quiz will be marked and contribute to their final grade. Students will also be evaluated on their research assignment on compressed gases. A brief report will be due next class, which will be Monday’s class; therefore students will have plenty of time to complete this task. |
| Compressed gases -Brainstorming determines what students know about compressed gases and see how it is related to our everyday life. Students will read through the text book pages 441 and 442 (1.5 pages of text). The class will then continue their discussion on compressed gases by sharing information that was not mentioned in the previous brainstorming activity. Students are required to take down any necessary notes – as all the material discussed is fair game for their unit test and exam. | **Activity:** Gas law Quiz
- 5 questions for Knowledge [ 5 K/U]
- 4 word problems [20 A]

Students will work independently or in pairs to answer the following questions from their text. Page 442 # 1 & 2.
- Questions will be taken up at the end of the activity |
| **Assignment:**
Student will research a compressed gas, and write a report on the type of gas, uses, proper storage methods and safety hazards. |
| 9.4 The Ideal Gas Law | F3.5 explain Dalton’s law of partial pressures, Boyle’s law, Charles’s law, Gay-Lussac’s law, the combined gas law, and the ideal gas law | **Lesson 1:** See Ideal Gas Law Lesson Plan  
**Lesson 2:**  
**Hook:** Make your own water boil in a syringe  
**Activity 1**  
The students will be able to work with a program on the web to see the relationship between all the variables in the Ideal Gas Law equation. They will have to complete a sketch of the graphs for all the relationships.  
[http://intro.chem.okstate.edu/1314F00/Laboratory/GLP.htm](http://intro.chem.okstate.edu/1314F00/Laboratory/GLP.htm)  
**Activity 2**  
The students will then have the rest of the period to finish the odd questions for the ideal gas law problems.  
Pg 445 & 446: # 1, 3, 5, 7 & 9 | **Lesson 1:** See Ideal Gas Law Lesson Plan  
**Lesson 2:**  
**Assessment**  
As the students are working with the program I will be going around asking them to change the y-axis to a different variable and to predict the new shape of the curve for me.  
**Evaluation**  
The students will be handing in their graph sketches which will be marked and given back to them. It will be marked based on organization, neatness and correctness. Their homework (odd questions) will be marked in the next class. | 2 Lessons  
2 Teaching |
| --- | --- | --- | --- |
| 9.5 Air Quality | F3.1 identify the major and minor chemical components of Earth’s atmosphere | **Lesson 1:** Computer Lab  
**Hook:** youtube video  
“Reveal Earth’s Atmosphere”  
[http://www.youtube.com/watch?v=1YAOT92wuD8&feature=related](http://www.youtube.com/watch?v=1YAOT92wuD8&feature=related)  
**Activity 1**  
Go through the components of Earth’s atmosphere and have the student take notes on the top 6.  
[http://sunshine.chpc.utah.edu/labs/atmosphere/atm_composition.swf](http://sunshine.chpc.utah.edu/labs/atmosphere/atm_composition.swf) | **Lesson 1:**  
**Assessment**  
Students will be formally assessed based on their notes and discussion during activities 1 & 2. They can be assisted by me in any areas that they are showing signs of struggling. I will be able to guide the flow of the activities based on the needs of the students.  
**Evaluation**  
The assignment that students will have to complete and hand in at the beginning of the next class. They will be required to surf the | 3 Lessons  
1 Teaching  
1 Work (Assign.)  
1 Present. |
| 10.3 The Ozone Layer | F2.3 solve quantitative problems by performing calculations based on Boyle’s law, Charles’s law, Gay-Lussac’s law, the combined gas law, Dalton’s law of partial pressures, and the ideal gas law [AI] |  |  |
| 10.5 Application and Careers with Gasses | F1.1 analyse the effects on air quality of some technologies and human activities (e.g., smelting; driving gas-powered |  |  |
F1.2 assess air quality conditions for a given Canadian location, using Environment Canada’s Air Quality Health Index, and report on some Canadian initiatives to improve air quality and reduce greenhouse gases (e.g., Ontario’s Drive Clean program to control vehicle emissions) [Al, C]

<table>
<thead>
<tr>
<th>Activity 2</th>
<th>Class Discussion on The Ozone Layer. Nasa’s web page for pictures, historical facts, and updates. <a href="http://www.nasa.gov/vision/earth/environment/ozone_resource_page.html">http://www.nasa.gov/vision/earth/environment/ozone_resource_page.html</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 3</td>
<td>Students will go to Environment Canada’s Air Quality Health Index web page to complete an assignment.</td>
</tr>
</tbody>
</table>

**Lesson 2: Computer Lab (groups of 3)**

The students will have the period to work on their assignments. They will be required to choose 5 Canadian cities and create a bar graph to represent the current air quality measure for each.

They will then look at ways to improve air quality and choose one of the links:

- Take action at home, on the road, at work, and at play. They will research a specific initiative and then make a presentation for the next class.

**Lesson 3: Classroom Presentations**

The groups of 3 will have approximately 5-7 min to present the initiative to improve air quality that they researched. They will then hand in their written component along with research and references.

Environment Canada’s Air Quality Health Index Website and complete the provided questions for marks.

What is the Air Quality Health Index (AQHI)? How is the AQHI calculated? What is the scale for the new AQHI?

This will be part of the overall assignment that is handed in at the end of Presentation (Lesson 3)

**Lesson 2: Assessment**

I will be able to go around the computer lab and provide help and have small discussions with the groups to see where they are in terms of the project.

**Evaluation**

The research that they gather will be developed into a written component and a presentation. The Presentation will be done during the next class and the written component will be handed after the presentation.

**Lesson 3: Evaluation**

The Presentations and written components will be marked based on the criteria I set for the project.
| 10.1 Mixtures of Gases | F3.5 explain Dalton's law of partial pressures, Boyle’s law, Charles’s law, Gay-Lussac’s law, the combined gas law, and the ideal gas law | Hook: Lung balloon demo. Explain that breathing and getting O₂ into the blood and CO₂ out of the blood works on diffusion and partial pressures. 
**Activity 1** 
Go through 2 questions to show how to solve partial pressures problems. (pg 461/462: Questions 1 & 2) Then do one with the class leading me through the problem. (pg 462: Question 3) 
**Activity 2** 
Students will be given to work on the remaining questions for the section of the textbook. 
Pg 462 – Q: 4 
Pg 463 – Q: 5-7 
Pg 465/466 – Q: 8-12 (not 7) & Q: 1-7 (not 3-5) | Assessment 
As the students are working on their worksheets I can circulate the class and look at the solutions they are producing. I will be able to give tips and suggestions where necessary as well as answer any questions the students may have about the material. 
**Evaluation** 
The students’ worksheet will be marked for homework. | 1 Lesson | 1 Teaching |
| --- | --- | --- | --- | --- |
| 10.2 Reactions of Gases | F3.6 explain Avogadro’s hypothesis and how his contribution to the gas laws has increased our understanding of the chemical reactions of gases | Hook: Real Life Can Crush [Link](http://www3.delta.edu/slime/cancrush.html) 
Show pictures at bottom of page and have discussion with students how this could have happened 
**Lecture/Note** on Law of Combing Values, Avogadro’s Theory, Molar Volume, Example Problems involving the three concepts 
**Demo:** Pop Can Crush (Melissa’s Demo) [Link](http://educ.queensu.ca/~science/main/concept/chem/c06/c06dek12.html) 
[Link](http://www.chem.uic.edu/marek/cgi-bin/vid7.cgi) | Assessment 
Assess students understanding of Avogadro’s Theory through discussion of Pop Can Crush Demonstration 
**Evaluation** 
Student’s homework will be marked for completion and understanding of the material. | 1 Lesson |
| 10.4 Gas Stoichiometry | **Homework/Class Work:**  
Nelson Grade 11 University Textbook  
p. 468 #3-5  
p.471 #7-12, 13abc, 14  
p. 474 #2-6 | **Lesson 1:** see to Melissa’s Lesson Plan for Details  
**Hook:** Exploding Pringle Can Demo  
[link](http://educ.queensu.ca/~science/main/concept/gen/g09/E.%20Kiepek/pringlescan.html)  
**Lecture/Socratic Dialogue:**  
Gas Stoichiometry Examples  
**Application**  
Gas Stoichiometry Assignment | **Lesson 1:**  
**Assessment**  
Assess students understanding of process of solving stoichiometry problems during Socratic dialogue between student and teacher during development of concept map and gas stoichiometry examples that are done on the board  
**Evaluation**  
Evaluate students understanding of solving gas stoichiometry assignment by having students hand-in assignment to be marked the day class after the work period  
**Lesson 2:**  
**Assessment/Evaluation**  
Quiz students on before Investigation 10.4.1 on gas stoichiometry problems | 3 Lessons  
2 Teaching  
1 Lab |
Lesson 3: Lab Period

Introduction and Instructions for Lab

Lab: Reaction of Hydrochloric Acid with Magnesium

Nelson Investigation 10.4.1 OR http://www.unit5.org/christjs/7mghcllab.doc

Lesson 3: Assessment

Observe students during lab activity for safety and understanding

Evaluation

have students hand in modified lab report/questions for marks

<table>
<thead>
<tr>
<th>Unit Review</th>
<th>Most – All expectations</th>
<th>Review Session – Have students tell teacher what topics/questions are going to be on the test and compile a list on the board</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Structure of Test – review with students the structure of the test (M/C, T/F, Matching, Short and Long Answer)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Review Problems Have students work in pairs or threes to complete the review questions. Have students help each other if they are struggling. Possible</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="http://www.unit5.org/christjs/Gas%20Review%20Problems.htm">http://www.unit5.org/christjs/Gas%20Review%20Problems.htm</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit Test</th>
<th>Most – All expectations</th>
<th>See Test</th>
</tr>
</thead>
</table>

Policy for Late Assignments

Work that is not handed in will be given a mark of zero. If the work is handed in before the assignment is handed back then it will be marked and graded. If the work is handed in after the assignment is given back, but handed in before the test it will be graded, but the weighting of the assignment would be changed so that the assignment reflects less of the student’s overall mark. If it’s not handed in by the test, but handed in before the last day of class for the term the assignment will be given a N/A and be removed from the marking so that it is not part of the student’s overall mark. If it is not handed in at all then the mark will remain a zero.

1 Lesson
## Breakdown of the Achievement Chart Categories

<table>
<thead>
<tr>
<th></th>
<th>Knowledge/Understanding</th>
<th>Thinking &amp; Investigation</th>
<th>Application</th>
<th>Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Breakdown of the Entire Unit</strong></td>
<td>20%</td>
<td>30%</td>
<td>30%</td>
<td>20%</td>
</tr>
<tr>
<td><strong>Breakdown of The Unit Test</strong> (out of 45 marks)</td>
<td>27%</td>
<td>22%</td>
<td>35%</td>
<td>16%</td>
</tr>
</tbody>
</table>

The unit is broken down this way to try and reflect the object of the unit. The goal is to try and teach students the skills of problem solving and critical thinking and so there is more emphasis on the Thinking & Investigation and Application Categories. These categories require the problem solving and critical thinking skills and allow the students to practice and develop them with the chemistry involved. It is important though to have a focus on Knowledge/Understanding and Communication and so the remaining Achievement Categories are still given a significant percentage.

The test is broken down to cover all the Achievement Categories. However, it is not an even 25% breakdown across all the categories because there are various assignments through the unit that will bring the test in-line with the entire unit breakdown. The test focuses on making the students think and apply the knowledge they have learned throughout the unit. It is trying to make use of the desired skills that are trying to be instilled in the students.
Instructions:

⚠️ You will have the entire period to complete the test (70 min)

⚠️ The test is made up of 4 sections:
  - Section A – Multiple Choice / True and False
  - Section B – Matching
  - Section C – Short Answer
  - Section D – Long Answer

⚠️ Please follow all instructions, which are indicated by the flask bullets

⚠️ Please read all questions carefully

⚠️ A mark breakdown of the test can be found on the next page

⚠️ Write your name on the top of every page and Good Luck!
## Mark Summary

<table>
<thead>
<tr>
<th>Section</th>
<th>Knowledge /Understanding</th>
<th>Thinking</th>
<th>Application</th>
<th>Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>/11</td>
<td>/2</td>
<td>/2</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>-</td>
<td>/6</td>
<td>-</td>
</tr>
<tr>
<td>C</td>
<td>-</td>
<td>/2</td>
<td>/7</td>
<td>/2</td>
</tr>
<tr>
<td>D</td>
<td>/1</td>
<td>/6</td>
<td>/1</td>
<td>/5</td>
</tr>
<tr>
<td><strong>Sub-Totals</strong></td>
<td><strong>/12</strong></td>
<td><strong>/10</strong></td>
<td><strong>/16</strong></td>
<td><strong>/7</strong></td>
</tr>
</tbody>
</table>

### Comments:

---

Name: ________________________________

Date: __________________

Chemistry SCH3U – Gases & Atmospheric Chemistry | Mr. Prosser

Page 14 of 22
Section A – Multiple Choice

Please read each question carefully and then circle the letter of the response that you feel is the most correct. (Approx. 10 min for multiple choice section – 1 min/question)

1) What are the top four gaseous components of our atmosphere (by percentage)?
   - A. Nitrogen, Oxygen, Hydrogen, Ozone
   - B. Nitrogen, Oxygen, Carbon Dioxide, Helium
   - C. Nitrogen, Oxygen, Argon, Hydrogen
   - D. Nitrogen, Oxygen, Argon, Carbon Dioxide

2) What is the correct balanced chemical equation?
   - A. H₂(g) + ½ O₂(g) → H₂O(g)
   - B. 3 H₂(g) + O₂(g) → 3 H₂O(g)
   - C. 2 H₂(g) + O₂(g) → H₂O(g)
   - D. H₂(g) + O₂(g) → H₂O(g)

3) Standard conditions of temperature and pressure (STP) are taken to be?
   - A. 25°C  760 mmHg
   - B. 298 K  1 atm
   - C. 273 K  1 atm
   - D. 0°C   76 mmHg

4) Given the units for pressure (atm), temperature (K), volume (L) and amount (mol) of a gas, what are the units for the gas constant (R) in the equation PV = nRT?
   - A. L⁻¹ atm⁻¹ mol⁻¹ K⁻¹
   - B. L atm mol⁻¹ K⁻¹
   - C. L⁻¹ atm mol⁻¹ K⁻¹
   - D. L atm⁻¹ mol⁻¹ K⁻¹
5) What are the three types of motion that gas molecules are capable of?

A. Angular, Rotational, Linear
B. Linear, Vibrational, Angular
C. Translational, Vibrational, Rotational
D. Rotational, Vibrational, Angular

6) As the temperature of a gas increases the gas molecules will increase in?

A. Potential Energy
B. Kinetic Energy
C. Electrical Energy
D. Total Energy

7) What statement best describes Boyle’s Law?

A. The volume of a fixed amount of gas at constant pressure is directly proportional to the temperature
B. At a fixed temperature and pressure, the volume of a gas is directly proportional to the amount of gas
C. For a fixed amount of gas at a constant temperature, gas volume is inversely proportional to gas pressure
D. The temperature of a gas is directly proportional to the average translational kinetic energy of its molecules

8) A 72.8 L constant volume cylinder containing 1.85 mol of He is heated until the pressure reaches 3.50 atm. What is the final temperature in degrees Celsius?

A. $1.41 \times 10^3 \degree C$
B. $1.41 \times 10^{-3} \degree C$
C. $1.41 \times 10^2 \degree C$
D. $1.41 \times 10^{-2} \degree C$
9) You have a fixed amount of O₂ gas with a volume of 2.0 L at constant pressure. The gas has an initial temperature of 293 K. If the gas is heated to 353 K, what will the new volume of the O₂ gas be (to the nearest decimal point)?

A. 2.7 L  
B. 3.0 L  
C. 2.0 L  
D. 2.4 L

10) The picture on the right represents a steel tank filled with hydrogen gas at 20°C and 3 atm. Which of the diagrams below would best illustrate the tank if the temperature were lowered to -20°C (Hydrogen freezes at -259°C)?

A.  
B.  
C.  
D.  

[ /1ₐ]  

[ /1ₜ]
Section A – True/False

⚠️ Please read the statements below and then indicate whether they are true or false by circling either true or false. (Approx. 5 min for true/false section – 1 min/question)

1) The kinetic energy of gas molecules is lower than liquid molecules.  
   True  False  [ /1K/U]

2) 1 mol of gas at STP will have a volume of 22.4 L.  
   True  False  [ /1K/U]

3) If the pressure of a fixed amount of gas at constant temperature is doubled the volume of that gas will also double.  
   True  False  [ /1K/U]

4) Hydrogen gas will react with oxygen gas in a 1:2 ratio to produce water (in the gaseous state).  
   True  False  [ /1K/U]

5) This graph below depicts Charles’s Law; the dotted line extending from the bottom left end of the red line represents a hypothetical gas that does not freeze. Assuming that all gases are hypothetical and do not freeze they would all have the same starting point on the graph.  
   True  False  [ /1T]
### Section B – Matching

You can rearrange and/or manipulate the ideal gas law equation \((PV = nRT)\) to solve for all the unknowns in column I. Place the letter of the derived gas law equation from column II beside the appropriate unknown in column I. (Approx. 5 min for matching section)

<table>
<thead>
<tr>
<th>Column I</th>
<th>Column II</th>
</tr>
</thead>
<tbody>
<tr>
<td>____ Molar Mass (M)</td>
<td>A. (= \frac{nRT}{P})</td>
</tr>
<tr>
<td>____ Density (D)</td>
<td>B. (= \frac{PV}{nR})</td>
</tr>
<tr>
<td>____ Mass (m)</td>
<td>C. (= \frac{mRT}{PV})</td>
</tr>
<tr>
<td>____ Temperature (T)</td>
<td>D. (= \frac{nRT}{V})</td>
</tr>
<tr>
<td>____ Moles (n)</td>
<td>E. (= \frac{MP}{RT})</td>
</tr>
<tr>
<td>____ Volume (V)</td>
<td>F. (= \frac{MPV}{RT})</td>
</tr>
</tbody>
</table>

Hue discovers the element of surprise...

Section C – Short Answer

⚠️ Answer the following questions in the space provided. Please be sure to show complete answers. (Approx. 20 min for short answer section)

1) You purchase a bag of potato chips at the beach snack stand for your picnic in the mountains. At the picnic the bag has inflated to the point of bursting. Use your knowledge of gas behaviour to explain, assume temperature is constant. [4 marks: 2 mark for (grammar/spelling/logical drawing), 2 marks for reasoning]

2) A 35.8 L cylinder of Ar (g) is connected to an empty 1875 L tank. If the temperature is held constant and the final pressure is 721 mmHg, what must have been the original gas pressure in the cylinder in atmospheres? Use the G.U.E.S.S. method. [3 marks: 1 mark for G.U., 1 mark for E.S., 1 mark for S.]
3) A 12.8 L cylinder contains 35.8 g O₂ at 46°C. What is the pressure of this gas, in atmospheres? Use the G.U.E.S.S. method. (R = 0.082057 L atm mol⁻¹ K⁻¹)

[4 marks: 2 mark for G.U., 1 mark for E.S., 1 mark for S.]

Section D – Long Answer

⚠️ Read the questions carefully and then provide your answer in the spaces provided.
(Approx. 20 min for long answer section)

a) Explain how an ordinary drinking straw in a glass of pop works in regards to pressure? You may use a diagram or words to explain.

[5 marks: 2 mark for logical diagram or correct grammar/spelling and arrangement, 3 marks for explanation]
b) What could you do to the straw so that you would no longer be able to drink the pop? Explain. [5 marks: 2 mark for grammar/spelling/arrangement, 3 marks for explanation]


c) Diet coke is less dense than regular coke, show the relationship between height of the straw \( h \) and density of the liquid \( d \) at constant pressure \( P \) and gravity \( g \), to show what type of pop could be pushed up a longer straw.


[3 marks: 1 mark for correct pop, 1 mark for equation, 1 mark for stating the relationship]

<table>
<thead>
<tr>
<th>Brand of pop that travels higher.</th>
<th>( \text{[}/1_{K/U}\text{]} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equation for height of straw using pressure, density and gravity.</td>
<td>( h = ) ( \text{[}/1_{A}\text{]} )</td>
</tr>
<tr>
<td>Relationship between height and density at constant pressure.</td>
<td>( \text{[}/1_{C}\text{]} )</td>
</tr>
</tbody>
</table>
Answer Key

Unit Test
Instructions:

⚠️ You will have the entire period to complete the test (70 min)

⚠️ The test is made up of 4 sections:
  o Section A – Multiple Choice / True and False
  o Section B – Matching
  o Section C – Short Answer
  o Section D – Long Answer

⚠️ Please follow all instructions, which are indicated by the flask bullets

⚠️ Please read all questions carefully

⚠️ A mark breakdown of the test can be found on the next page

⚠️ Write your name on the top of every page and Good Luck!
# Mark Summary

<table>
<thead>
<tr>
<th>Section</th>
<th>Knowledge /Understanding</th>
<th>Thinking</th>
<th>Application</th>
<th>Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>/11</td>
<td>/2</td>
<td>/2</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>-</td>
<td>/6</td>
<td>-</td>
</tr>
<tr>
<td>C</td>
<td>-</td>
<td>/2</td>
<td>/7</td>
<td>/2</td>
</tr>
<tr>
<td>D</td>
<td>/1</td>
<td>/6</td>
<td>/1</td>
<td>/5</td>
</tr>
<tr>
<td><strong>Sub-Totals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>/12</strong></td>
<td><strong>/10</strong></td>
<td><strong>/16</strong></td>
<td><strong>/7</strong></td>
</tr>
</tbody>
</table>

**Comments:**
Section A – Multiple Choice

Please read each question carefully and then circle the letter of the response that you feel is the most correct. (Approx. 10 min for multiple choice section – 1 min/question)

1) What are the top four gaseous components of our atmosphere (by percentage)? [ /1k/u]

A. Nitrogen, Oxygen, Hydrogen, Ozone
B. Nitrogen, Oxygen, Carbon Dioxide, Helium
C. Nitrogen, Oxygen, Argon, Hydrogen
D. Nitrogen, Oxygen, Argon, Carbon Dioxide [1 mark]

2) What is the correct balanced chemical equation? [ /1k/u]

A. \( \text{H}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{g}) \) [1 mark]
B. \( 3 \text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 3 \text{H}_2\text{O}(\text{g}) \)
C. \( 2 \text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{g}) \)
D. \( \text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{g}) \)

3) Standard conditions of temperature and pressure (STP) are taken to be? [ /1k/u]

A. 25°C 760 mmHg
B. 298 K 1 atm
C. 273 K 1 atm [1 mark]
D. 0°C 76 mmHg

4) Given the units for pressure (atm), temperature (K), volume (L) and amount (mol) of a gas, what are the units for the gas constant (R) in the equation \( PV = nRT \)? [ /1k/u]

A. \( \text{L}^{-1} \text{ atm}^{-1} \text{ mol}^{-1} \text{ K}^{-1} \)
B. \( \text{L atm mol}^{-1} \text{ K}^{-1} \) [1 mark]
C. \( \text{L}^{-1} \text{ atm mol}^{-1} \text{ K}^{-1} \)
D. \( \text{L atm}^{-1} \text{ mol}^{-1} \text{ K}^{-1} \)
5) What are the three types of motion that gas molecules are capable of? [1 mark]

A. Angular, Rotational, Linear
B. Linear, Vibrational, Angular
C. Translational, Vibrational, Rotational
D. Rotational, Vibrational, Angular

6) As the temperature of a gas increases the gas molecules will increase in? [1 mark]

A. Potential Energy
B. Kinetic Energy
C. Electrical Energy
D. Total Energy


A. The volume of a fixed amount of gas at constant pressure is directly proportional to the temperature
B. At a fixed temperature and pressure, the volume of a gas is directly proportional to the amount of gas
C. For a fixed amount of gas at a constant temperature, gas volume is inversely proportional to gas pressure
D. The temperature of a gas is directly proportional to the average translational kinetic energy of its molecules

8) A 72.8 L constant volume cylinder containing 1.85 mol of He is heated until the pressure reaches 3.50 atm. What is the final temperature in degrees Celsius? [1 mark]

A. 1.41 \times 10^3 \degree C
B. 1.41 \times 10^{-3} \degree C
C. 1.41 \times 10^2 \degree C
D. 1.41 \times 10^{-2} \degree C
9) You have a fixed amount of O₂ gas with a volume of 2.0 L at constant pressure. The gas has an initial temperature of 293 K. If the gas is heated to 353 K, what will the new volume of the O₂ gas be (to the nearest decimal point)?

A. 2.7 L  
B. 3.0 L  
C. 2.0 L  
**D. 2.4 L**  

[1 mark]

10) The picture on the right represents a steel tank filled with hydrogen gas at 20°C and 3 atm. Which of the diagrams below would best illustrate the tank if the temperature were lowered to -20°C (Hydrogen freezes at -259°C)?

A.  
B.  
C.  
D.  

[1 mark]
Section A – True/False

⚠️ Please read the statements below and then indicate whether they are true or false by circling either true or false. (Approx. 5 min for true/false section – 1 min/question)

1) The kinetic energy of gas molecules is lower than liquid molecules. True False [1 mark]

2) 1 mol of gas at STP will have a volume of 22.4 L. True False [1 mark]

3) If the pressure of a fixed amount of gas at constant temperature is doubled the volume of that gas will also double. True False [1 mark]

4) Hydrogen gas will react with oxygen gas in a 1:2 ratio to produce water (in the gaseous state). True False [1 mark]

5) This graph below depicts Charles’s Law; the dotted line extending from the bottom left end of the red line represents a hypothetical gas that does not freeze. Assuming that all gases are hypothetical and do not freeze they would all have the same starting point on the graph. True False [1 mark]
**Section B – Matching**

⚠️ You can rearrange and/or manipulate the ideal gas law equation \((PV = nRT)\) to solve for all the unknowns in column I. Place the letter of the derived gas law equation from column II beside the appropriate unknown in column I. (Approx. 5 min for matching section)

<table>
<thead>
<tr>
<th>Column I</th>
<th>Column II</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1 mark]</td>
<td><strong>C</strong> Molar Mass ((M))</td>
</tr>
<tr>
<td>[1 mark]</td>
<td><strong>E</strong> Density ((D))</td>
</tr>
<tr>
<td>[1 mark]</td>
<td><strong>F</strong> Mass ((m))</td>
</tr>
<tr>
<td>[1 mark]</td>
<td><strong>B</strong> Temperature ((T))</td>
</tr>
<tr>
<td>[1 mark]</td>
<td><strong>G</strong> Moles ((n))</td>
</tr>
<tr>
<td>[1 mark]</td>
<td><strong>A</strong> Volume ((V))</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Chemistry SCH3U – Gases & Atmospheric Chemistry | Mr. Prosser](http://www.jtrue.com/cartoons/art/low/element_of_surprise.jpg)

[6 marks]
**Section C – Short Answer**

⚠️ Answer the following questions in the space provided. Please be sure to show complete answers. (Approx. 20 min for short answer section)

1) You purchase a bag of potato chips at the beach snack stand for your picnic in the mountains. At the picnic the bag has inflated to the point of bursting. Use your knowledge of gas behaviour to explain, assume temperature is constant. [4 marks: 2 mark for (grammar/spelling/logical drawing/labels), 2 marks for reasoning]

- Pressure decreases at higher altitudes ➔ [1 mark (T)]
- Volume increases as Pressure decreases ➔ [1 mark (T)]

[2 mark (C)] Spelling/Grammar OR Overall Logical Drawing

2) A 35.8 L cylinder of Ar (g) is connected to an empty 1875 L tank. If the temperature is held constant and the final pressure is 721 mmHg, what must have been the original gas pressure in the cylinder in atmospheres?

   Use the G.U.E.S.S. method. [3 marks: 1 mark for G.U., 1 mark for E.S., 1 mark for S.]

   G: $V_1 = 35.8 \text{ L}$  $V_2 = 1910.8 \text{ L}$  ($V_2 = 1875 \text{ L} + 35.8 \text{ L}$)  $P_2 = 721 \text{ mmHg}$

   U: $P_1 =$ [1 mark]

   E: $P_1V_1 = P_2V_2$  $P_1 = P_2V_2/V_1$  [1 mark]

   S: $P_1 = (721 \text{ mmHg}) (1910.8 \text{ L}) / (35.8 \text{ L})$  * (1 atm / 760 mmHg)

   $P_1 = 50.6 \text{ atm}$  [1 mark]

   S: :: the original gas pressure in the cylinder was 50.6 atm.
3) A 12.8 L cylinder contains 35.8 g O₂ at 46°C. What is the pressure of this gas, in atmospheres? Use the G.U.E.S.S. method. (R = 0.082057 L atm mol⁻¹ K⁻¹) [4 marks: 2 mark for G.U., 1 mark for E.S., 1 mark for S.]

\[ \begin{align*}
\text{G: } & \quad V = 12.8 \text{ L} \quad m(\text{O}_2) = 35.8 \text{ g} \quad T = 46^\circ \text{C} = 319 \text{ K} \quad M(\text{O}_2) = 32 \text{ g/mol} \\
& \quad R = 0.082057 \text{ L atm mol}^{-1} \text{ K}^{-1} \\
\text{U: } & \quad P = ? \\
\text{E: } & \quad PV = nRT \rightarrow PV = \frac{mRT}{M} \rightarrow P = \frac{mRT}{MV} \\
\text{S: } & \quad P = \frac{(35.8 \text{ g}) (0.082057 \text{ L atm mol}^{-1} \text{ K}^{-1}) (319 \text{ K})}{(16 \text{ g/mol}) (12.8 \text{ L})} \\
& \quad P = 2.29 \text{ atm} \\
\end{align*} \]

[S: ∴ the pressure of the gas is 2.29 atm.]

Section D – Long Answer

Read the questions carefully and then provide your answer in the spaces provided. (Approx. 20 min for long answer section)

a) Explain how an ordinary drinking straw in a glass of pop works in regards to pressure? You may use a diagram or words to explain. [5 marks: 2 mark for logical diagram or correct grammar/spelling and arrangement, 3 marks for explanation]

Person sucks on the straw removing all the air (no pressure in straw)

- Atmosphere pushes down on drink with constant pressure

- No pressure in the straw the atmospheric pressure pushes the drink up the straw into the person’s mouth

[2 mark (C)] Diagram + Labels OR Spelling/Grammar + Arrangement
b) What could you do to the straw so that you would no longer be able to drink the pop? Explain. [5 marks: 2 mark for grammar/spelling/arrangement, 3 marks for explanation]

- Make the straw longer [1 mark (T)]

- Once the straw reaches a certain length the liquid (with a certain density) will not be pushed up the straw by the atmospheric pressure [1 mark (T)]

Spelling/Grammar and Arrangement [2 mark (C)]

b) Diet coke is less dense than regular coke, show the relationship between height of the straw (h) and density of the liquid (d) at constant pressure (P) and gravity (g), to show what type of pop could be pushed up a longer straw. [3 marks: 1 mark for correct pop, 1 mark for equation, 1 mark for stating the relationship]

| Brand of pop that travels higher. | Diet Coke travels higher up the straw because it is less dense than coke. [1 mark (K/U)] |
| Equation for height of straw using pressure, density and gravity. | \( h = \frac{P}{d \cdot g} \) [1 mark (A)] |
| Relationship between height and density at constant pressure. | Height is inversely proportional to density Or Height increases as density decreases [1 mark (C)] |
Appendix

Lesson Plans & Additional Resources

(Andrea Wylie, Bejay Prosser & Melissa Provost)
## 1. Instructional Expectations and Opportunities

### a) Expectations:

#### Overall Expectations:
- demonstrate an understanding of the laws that govern the behaviour of gases;

#### Specific Expectations:
- F3.5 explain Dalton’s law of partial pressures, Boyle’s law, Charles’s law, Gay-Lussac’s law, the combined gas law, and the ideal gas law

- F2.3 solve quantitative problems by performing calculations based on Boyle’s law, Charles’s law, Gay-Lussac’s law, the combined gas law, Dalton’s law of partial pressures, and the ideal gas law [AI]

### b) Opportunities:

#### Cross-curriculum:
Math – as students will apply mathematics skills to solve problems pertaining to the gas laws.

#### Future Expectations:
With the knowledge of the Boyle’s and Charles’ Gas Laws, students will be able to expand their knowledge when introduced to the combined gas law as well as the ideal gas law.

#### Life Skills:
- **Listening skills** (students are required to listen to the teacher’s instructions, as they will have to answer questions that pertain to what the teacher said.)
- **Co-operation with classmates** – (Students will have to co-operate and communicate with other students when participating in class discussions. Students are expected to show respect to their peers when discussing ideas.)
- **Social / Public speaking** – (Students should speak with good purpose when working in the classroom.)
- **Organizational Skills** – (Students are always required to keep their notes organized.)

### Associate/Advisor Comments:

## 2. Preassessment and Accommodations/Modifications

### a) Students

There are no IEP students that require accommodations and modifications.
b) Learning Environment:

The teacher will be at their desk when conducting the demo. Throughout the class discussion, the teacher will be walking around the class to ensure each student is paying their fullest attention. Also when conducting the Boyle’s apparatus activity, the teacher will be walking around so that each student can see clearly. When working through math problems, the teacher will be at the board writing the answer down for all the students to see. If students are recording answers on the board, the teacher will move to where the students are sitting to analyze the answer and ensure there are no errors.

Associate/Advisor Comments:

3. Required Resources

Hook:
- Pop cans 4 or 5 (just in case it doesn’t work perfectly).
- 2 hotplates
- Tongs
- Tub

Lesson:
- Textbook: Nelson Chemistry 11
- Boyle’s Apparatus

Homework Assignment:
- Boyle’s and Charles’ Law Handout – See Appendix
4. Content and Teaching Strategies of Lesson

a) Overview/Agenda/Review

1. Hook: Pop Can Crusher
3. Boyle’s Law
4. Charles’ Law
5. A simulation of Gas Properties (Answers)
6. Homework assignment

b) Subject Content and Teaching Strategies

I. SUBJECT CONTENT

<table>
<thead>
<tr>
<th>Content Name</th>
<th>Content Details</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SEE DETAILS BELOW</td>
</tr>
</tbody>
</table>

II. INTRODUCTION (motivational start, minds-on, hook, etc.)

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pop Can Crusher - Hook</td>
<td>The teacher will heat up a few pop cans filled with a little bit of water. When there is a strong stream of steam the teacher will use tongs and invert the can into a tub of water. Students will observe the pressure change with instantly causes the can to crush. The teacher will not explain it to the students because it will appear in a video clip in later lessons, where a class discussion will occur.</td>
<td>3 Minutes</td>
</tr>
</tbody>
</table>

III. INSTRUCTION AND APPLICATION

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Timing</th>
</tr>
</thead>
</table>
| Introduction: A simulation of Gas Properties. | - Students will open their textbooks to page 423  
- The teacher will explain the scenario and have the students in a discussion form come up with what cylinder they think will explode and explain the logic behind their thinking.  
- This will take the form of a discussion to allow the teacher to determine what the students already know on the topic of gases. It will also get the students thinking of the properties of gases.  
- While the students are explaining their predictions, the teacher will be recording them on the board so that students can visually see it and refer to it as ideas continue to flow.  
- The assignment will be left unanswered (correct answer) until the end of class, after the gas laws have been discussed.  
- From the last question on page 423, the teacher will note the variables that need to be considered when dealing with gases. | 10 minutes |
Boyle’s Law

The relationship between Pressure and Volume: Boyle’s Law

- The variables from the previous exercise will be used to introduce the different laws.

**Teacher:** As you have mentioned, we can investigate the properties of gases in a laboratory by using these variables. “How do you think you can use the variables to determine the properties?”

**Anticipated response:** “You would have to determine the effect one has on the other and how they are related.”

**Teacher:** “Exactly, so if you manipulate one variable than you will be able to observe its effect on another variable”.

**Teacher:** “Ok so let’s see what kind of an effect pressure has on volume. First what would you have to do if you just want to look at pressure and volume, what would have to be true about the other variables?”

**Anticipated response:** “They would have to be constant.”

**Teacher:** So let’s use ourselves as an example. Gravity is pushing down on us with force and in turn we exert an equal force on the ground. What happened when we are outside in the winter and we are walking across thick snow?”

**Anticipated response:** “We sink into the snow.”

**Teacher:** “How many people have gone snowshoeing before? (Wait for hands) Why is it that when you are wearing snowshoes you don’t sink?”

**Anticipated response:** “With a larger surface area that your weight is distributed on, from the snowshoe, you exert less pressure on the ground below your feet and that is why you don’t sink.”

**Teacher:** “Excellent!”

The teacher will use this Boyles Apparatus shown below to facilitate a discussion with the class and introduce Boyle’s Law.

30 minutes
Anticipated response: “Air”

Teacher: “Exactly so now we have a volume of gas. What would happen if I were to push down on it what would happen?”

Anticipated response: “You would be exerting pressure on the cylinder which would cause some of the air (gas) to leave. Therefore you are decreasing the volume.”

Teacher: “Yes you are right about exerting pressure, but you think that if I push down on it all of the gas will leave?”

Anticipated response: “Well you have a certain amount of gas and because the air cannot enter or leave the cylinder than when you push it down it will not move, it will be stuck because air does take up space.”

Teacher: “Very good let’s give it a try.” The teacher will have a student push down on the syringe to see what will happen.

“What happened?”

Anticipated response: “Well the syringe ended up going lower than we initially thought.”

Teacher: “Exactly, why do you think it is able to go down further?”

Anticipated response: “The kinetic molecular theory was talking about how gas molecules are farther apart, so if you were to exert pressure on the gas, then the molecules will just get pushed together therefore resulting in a smaller volume. The gas is compressed as small as it can possibly go.”

Teacher: “Excellent, so when I initially filled the syringe with air it was at its natural state occupying 40 mL. So after being compressed, when you let go of the syringe it will pop up back to 40 mL, back to its natural state.”

Teacher: “What do you think would happen if I pulled the syringe all the way up?”

Anticipated response: “Well since we have discovered that no air is entering or leaving (the amount of air is constant) than the volume of the contain will be increasing, creating more space for the gas molecules to spread out. When gas molecules are more spread out its volume is made of mostly empty space.”

Teacher: “Explain the pressure when you push the syringe back down?”

Anticipated response: “it will be easy to get the syringe back to its starting point because the volume is mostly empty space now.”

Teacher: “So it is fair to say that when you increase the volume of a gas you are decreasing the pressure. When you decrease the volume of a gas you are increasing its pressure.”

“This is known as Boyle’s Law, named after Robert Boyle who discovered this relationship.”

The teacher will have a student read Boyles Law aloud while they right it on the board for the students to copy down.
**Boyle’s Law:** as the pressure on a gas increases, the volume of the gas decreases proportionally, provided that the temperature and amount of gas remain constant.

**Teacher:** “In other words the volume is inversely related to the pressure, provided that the temperature and the amount of gas don’t change.”

**Teacher:** “Boyle’s law can be written like this, \( v \propto \frac{1}{P} \) showing that it is inversely proportional or it can also be expressed as \( p_1v_1 = p_2v_2 \). How would you rearrange this equation to solve for \( p_2 \), which is the new pressure?” (both of these expressions will be on magnets on the white board so that students can practice rearranging equations when they need to.

**Anticipated response:** “You would have to divide the right side by \( v_2 \) to cancel them out, and what you do to one side you must do to the others. So than the result would be \( p_2 = \frac{p_1v_1}{v_2} \).” (The student will be asked to come up and show how they arrived to the final equation).

**Teacher:** “Let’s try an example problem.”

A 2.0-L party balloon at 98 kPa is taken to the top of a mountain where the pressure is 75 kPa. Assume the temperature is the same. What is the new volume of the balloon?

**Teacher:** “What must we do first?”

**Anticipated response:** “You would have to indicate the values we have to start with. So we have \( v_1 = 2.0 \) L, \( p_1 = 98 \) kPa and \( p_2 = 75 \) kPa.”

As the student is answer the question the teacher will be going step by step through the answer so that students can follow easily and record everything in their notes.

The end result will look like this (with probing from the teacher). The teacher will stress the use of the GUESS method (Given, Unknown, Equation, Substitute, Solve)

| G: | \( v_1 = 2.0 \) L  
| U: | \( p_1 = 98 \) kPa  
| E: | \( p_2 = 75 \) kPa  
| S: | \( v_2 = ? \)  
| S: | \( p_1v_1 = p_2v_2 \)  
| S: | \( v_2 = \frac{p_1v_1}{p_2} \)  
| S: | \( = \frac{98 \text{ kPa} \times 2.0 \text{ L}}{75 \text{ kPa}} \)  
| S: | \( = 2.6 \text{ L} \)  
| S: | **or** \( v_{\text{balloon}} = 2.0 \text{ L} \times \frac{98 \text{ kPa}}{75 \text{ kPa}} = 2.6 \text{ L} \)  

The new volume of the balloon is 2.6 L.

**Practice Questions:** Textbook page 428 #6-9
The relationship between Volume and temperature: Charles’ Law

Teacher: “Let’s talk about the effects that temperature has on volume. The relationship between volume and temperature is known as Charles Law, after the French physicist Jacques Charles. “

The teacher will have a student read Charles’ Law aloud while they right it on the board for the students to copy down.

Charles’ Law: as the temperature of a gas increases, the volume increases proportionally, provided that the pressure and amount of gas remain constant.

Teacher: “In other words the volume is proportionate to the temperature, provided that the pressure and the amount of gas don’t change.”

Teacher: “Charles’ law can be written like this, v α T showing that it is proportional or it can also be expressed as v1/T1 = v2/T2. How would you rearrange this equation to solve for T2, which is the new temperature?” (both of these expressions will be on magnets on the white board so that students can practice rearranging equations when they need to.

Anticipates response: “You begin by multiplying the right side by T2 to cancel it out and what you do to one side you must do to the other. Now that you have T2v1/T1 = V2. You would then multiply the left side by T1 to cancel it out and again what you do to one side you must do to the other. After that you would divide the left side by v1 to cancel it out and it would result in the division of v1 on the right side.”

(The student will be asked to come up and show how they arrived to the final equation).

Teacher: “Are there any questions with how to do this?” If there are questions, the teacher will work through more examples where the students that don’t understand will work through it on the board.

Teacher: “Before we doing practice problems, there is something we all must do when working with temperature. Can anyone tell me what that might be?”

Anticipated Response: “Converting the temperature to Kelvin.” It is expected that there will be some students who are keen and will either read ahead or have their textbook open indicating the answer.

Teacher: “Yes, we must always work with temperature in Kelvin. In order to convert the temperature we must add 273 to the amount in Celsius. It was determined that if a gas does not liquefy its volume would become 0 at -273°C. This temperature is absolute zero meaning that it is the lowest possible temperature. Kelvin (K) is named after Lord Kelvin who created the absolute zero scale. So since -273°C = 0K than in order to convert Celsius to K we just simply add 273.”

Teacher: “Let’s work through a sample problem.”

A gas inside a cylinder with a movable piston is to be heated to 315°C. The volume of gas in the cylinder is 0.30 L at 25°C. What is the final volume when the temperature is 315°C?

Teacher: “Again what is the first thing we must do?”
Anticipated response: “You would have to indicate the values we have to start with. So we have \( v_1 = 0.30 \text{ L}, T_1 = 25^\circ \text{C} \) and \( T_2 = 315^\circ \text{C} \).”

As the student is answering the question, the teacher will be going step by step through the answer so that students can follow easily and record everything in their notes.

The end result will look like this (with probing from the teacher). The teacher will stress the use of the GUESS method (Given, Unknown, Equation, Substitute, Solve)

### Solution

\[
\begin{align*}
G: & \quad v_1 = 0.30 \text{ L} \\
T_1 &= 25^\circ \text{C} = 298 \text{ K} \\
v_2 &= ? \quad T_2 = 315^\circ \text{C} = 588 \text{ K} \\
\frac{v_1}{T_1} &= \frac{v_2}{T_2} \\
v_2 &= \frac{v_1 T_2}{T_1} \\
&= \frac{0.30 \text{ L} \times 588 \text{ K}}{298 \text{ K}} \\
v_2 &= 0.59 \text{ L} \\
\text{or} \quad v_{N_2} &= 0.30 \text{ L} \times \frac{588 \text{ K}}{298 \text{ K}} \\
&= 0.59 \text{ L} \\
\end{align*}
\]

The final volume of the nitrogen gas at \( 315^\circ \text{C} \) is 0.59 L.

### Practice Questions: Textbook page 434 #16-19

Results from introduction activity: simulation of Gas Properties.

Students will work through the introduction activity from their textbook on page 423. After student read through it again, the teacher will engage a class discussion where the students will formulate a new explanation based on the knowledge (laws) discussed in this lesson.

Solution:

<table>
<thead>
<tr>
<th>Results from introduction activity: simulation of Gas Properties.</th>
<th>7 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Suppose five nitrogen gas cylinders are assembled using the conditions listed in Table 1. Each cylinder contains the same mass of nitrogen gas.

<table>
<thead>
<tr>
<th>Cylinder number</th>
<th>Volume (L)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0</td>
<td>800</td>
</tr>
<tr>
<td>2</td>
<td>2.0</td>
<td>200</td>
</tr>
<tr>
<td>3</td>
<td>2.0</td>
<td>300</td>
</tr>
<tr>
<td>4</td>
<td>4.0</td>
<td>200</td>
</tr>
<tr>
<td>5</td>
<td>4.0</td>
<td>800</td>
</tr>
</tbody>
</table>

Cylinder most likely to explode:
1
5
3
2
4

Cylinder least likely to explode:

These results are based on Charles law where a smaller volume is proportional to temperature. Students will also have to use their understanding of Boyle’s law where if there is an increase in volume there will be a decrease in pressure. Using this information, students will be able to deduce that the smaller volumes with the larger temperature will result in cylinders that are most likely to explode.

The teacher will continue to probe for the answer with correct explanations.

### IV. CONSOLIDATION

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick Questions</td>
<td>Student will be given any time left over in the class to complete practice questions or to work on the homework handout. Prior to dismissal, the teacher will ask some quick questions based on the relationships between volume and pressure and volume and temperature. Some of the questions will also be a review of the previous lesson. Questions: If temperature increases what happens to the volume? If pressure is doubles what happens to the volume? What are the conditions at STP? SATP? 2 atm is converted to what in mmHg? What is the temperature in Kelvin at STP? How does an manometer work? The teacher will distribute the Practice Problem Handout which is to be completed for homework.</td>
<td>5 minutes</td>
</tr>
</tbody>
</table>
5. Assessment and Evaluation

Assessment:
Students will be assessed throughout the lesson based on their contribution to the class discussions. In addition, the teacher will walk around the class as students work through the practice problems (at the end of both Boyle’s and Charles law discussion). The teacher will be assessing each student’s progress and understanding of the material taught in today’s and previous lessons. Today’s lesson includes a brief activity that will be answered at the end of the lesson. Students will be assessed based on their contribution to solving the problem.

Students will also be assessed on what they have learned and what they still don’t understand. This will be done through the consolidation exercise.

Evaluation:
Students will be required to complete the homework handout that includes Boyle’s and Charles law questions. Students will be submitting this small exercise for evaluation purposes which is due next class. By having the student submit it for marks, students will receive full feedback on their work and have an example of what to expect for the test and exam. The assignment will be out of 51 marks, where the first question will be worth 6 marks towards communication, while the rest of the questions are worth 5 marks each towards application.

Although students are not submitting an activity for marks during this lesson, in the future lessons students will write a quiz based on today’s knowledge along with other lessons. Students will also be required to complete and submit a lab activity that will be marked and contribute to the final mark. In addition, the information taught in today’s lesson will also be present on the test at the end of the unit.
Practice Questions
Boyle’s and Charles’ Law

1. Draw a graphical representation of both Boyle’s and Charles’ Law

2. In Vancouver, a balloon with a volume of 5.0 L is filled with air at 101 kPa pressure. The balloon is then taken to Banff, where the atmospheric pressure is only 91 kPa (Banff is 1386 m above sea level). Will the balloon’s volume be larger or smaller at Banff? If the temperature is the same in both places, what will the new volume of the balloon be?

3. A certain mass of gas in a 2.00L container has a pressure of 164 kPa. Calculate the new pressure of the gas if the volume of the container is reduced to 1.00L.
4. A balloon is filled with a gas at a pressure of 102 kPa, and its volume is determined to be 1.37 L. Calculate the volume of the balloon if the pressure increases to 100 kPa after more gas is added.

5. A shampoo bottle contains 443 mL of air at 65°C. What is its volume when it cools to 22°C?

6. In an experiment, the volume of a container of gas is reduced to one-third of its original volume. Predict the relative change in pressure.
7. A diver’s lungs hold about 20.0 L of air underwater at a pressure of 875 mm Hg. Assuming he holds his breath and his lungs don’t burst, what will be the volume of air in his lungs at standard pressure on the water’s surface?

8. A balloon contains 5.00L of air at 25⁰C. Deduce at what temperature the balloon will shrink to half that volume. Assume that the pressure is held constant.
9. A 250 cm³ sample of neon is collected at 44.0°C. What would be the volume of the neon at standard temperature?

10. A sample of oxygen gas has a volume of 2.73 dm³ at 21.0°C. At what temperature would the gas have a volume of 4.00 dm³?
Subject / Course: Chemistry  
TC Name: Ms. Wylie Prossvost  
Grade Level: Grade 11  
Date: March 5, 2098  
Topic: Gases and Atmospheric Chemistry  
Time of Class: 12:35 – 1:50 (75 minutes)  
AT Name: Mr. Dufresne  
Room # / Location: 307

1. Instructional Expectations and Opportunities

a) Expectations: (approx. 1-3 expectations from the Ontario Curriculum that could be assessed)

- F3.5 explain Dalton’s law of partial pressures, Boyle’s law, Charles’s law, Gay-Lussac’s law, the combined gas law, and the ideal gas law
- F3.4 describe, for an ideal gas, the quantitative relationships that exist between the variables of pressure, volume, temperature, and amount of substance
- F2.3 solve quantitative problems by performing calculations based on Boyle’s law, Charles’s law, Gay-Lussac’s law, the combined gas law, Dalton’s law of partial pressures, and the ideal gas law

b) Opportunities: (approx. 2+ other learning opportunities such as other expectations not assessed, other learning that happens as a result of the lesson e.g., organization, group, listening, co-operation, reading, writing skills etc.)

Cross-Curricular
- Biological systems & Partial Pressures
- Physics: Gas Laws

Life Skills
- Problem Solving
- Critical Thinking
- Group/Cooperation skills

Associate/Advisor Comments:

2. Preassessment and Accommodations/Modifications

a) Students
(consider the students you will be teaching and anything that will affect their learning or your teaching strategies (e.g., include academic, behavioural & social/emotional, physical and diversity needs, + provide accommodations/modifications - how you will differentiate learning for each student and/or type of need – N.B. use initials of students rather than full names)

Preassessment:  
Accommodation/Modification:

There are no IEP students that require accommodations and modifications.
b) Learning Environment:
(describe the learning environment such as the set up/location of desks, where audio-visual equipment will be, where the teacher stands, where the students are working etc. – you may wish to include a map/layout of the classroom on a separate sheet and reference it with modifications if lesson changes)

![Diagram of classroom layout]

The teacher will be at their desk when showing the video. Throughout the class the teacher will be walking around the class to ensure each student is paying their fullest attention. Also when conducting the exploration activities, the teacher will be walking around asking questions and assisting the students.

Associate/Advisor Comments:

3. Required Resources

(list ALL resources required to conduct this lesson with detailed specifics such as textbook titles, chapters, page numbers, author/publishers, website URLs, resources like paper, pencils, protractors, chalk, rulers, paint, specimens, books, maps, videos, posters, lab materials, handouts – include name of handout and number of copies, etc.)

- Laptop/Projector/Internet Connection
- Meter stick, tape, scissors, stiff cardboard
- Basketball, soccer ball, orange juice jugs, pop bottles
- Dry Ice, clear plastic garbage bags (49 L), plastic ties, balance
- Textbook
### 4. Content and Teaching Strategies of Lesson

#### a) Overview/Agenda/Review
(consider a quick overview of the lesson and/or list key elements in lesson which may be written on white/blackboard as an agenda for students and you to follow, you may also choose to consider a review of previous day’s work)

Hook: - Water boiling at room temperature  
Activity 1: Direct instruction – Variable Relationships  
Activity 2: Group Exploration (STP/ideal gas law)  
Activity 3: Independent work – Practice Problems/Homework  
Consolidation: Take up first homework question

#### b) Subject Content and Teaching Strategies (This section includes the details of the lesson’s subject content and how this content will be organized and implemented for student learning)

I. **SUBJECT CONTENT** (only list content related material – NOT how you will teach it; this section is a reference section for you, the teacher or anyone else who uses your lesson plan, regarding content; might include diagrams, facts, maps, definitions, terminology, examples, anything that may be necessary for you to understand to address students’ questions, extend their thinking or scaffold learning;)

<table>
<thead>
<tr>
<th>Content Name</th>
<th>Content Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideal Gas Law</td>
<td>PV = nRT</td>
</tr>
<tr>
<td>Gas Constant (R)</td>
<td>R = 0.08206 L atm / mol·K</td>
</tr>
<tr>
<td></td>
<td>= 8.3145 L kPa / mol·K</td>
</tr>
<tr>
<td></td>
<td>= 8.3145 J / mol·K</td>
</tr>
<tr>
<td></td>
<td>= 1.987 cal / mol·K</td>
</tr>
<tr>
<td></td>
<td>= 62.364 L torr/ mol·K</td>
</tr>
<tr>
<td></td>
<td>Notes:</td>
</tr>
<tr>
<td></td>
<td>1 atm = 101.32 kPa</td>
</tr>
<tr>
<td></td>
<td>1 J = 1 L kPa</td>
</tr>
<tr>
<td></td>
<td>1 cal = 4.182 J</td>
</tr>
<tr>
<td></td>
<td>1 atm = 760 torr</td>
</tr>
</tbody>
</table>

II. **INTRODUCTION** (motivational start, minds-on, hook, etc.) (describe how you will motivate students, get their attention, relate the lesson to their lives, such as a minds-on activity, a hook or an activity that will pull learners into lesson – ensure you provide a step-by-step description of this introduction with an approximate timing)

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Boiling at Room Temp.</td>
<td>Video <a href="http://www.youtube.com/watch?v=9q5gEZGoBnk">http://www.youtube.com/watch?v=9q5gEZGoBnk</a></td>
<td>~ 3 min</td>
</tr>
</tbody>
</table>

III. **INSTRUCTION** (this details how you will organize the content for student learning; include strategies and EXACT sequence of instruction; similar to a script—your statements, actions, students’ actions, transitions, distribution of material, guiding questions AND students’ anticipated responses; include sufficient white space for easy reference; include approximate timing) **AND**

**APPLICATION** (How will the students apply their new learning? This typically follows Instruction BUT it could be incorporated as part of the Instruction. Examples include role playing the parts of a cell, solving problems, worksheet, labelling a diagram, making a model, creating a mind-map, etc.)

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 1</td>
<td>Whiteboard</td>
<td>~ 20 min</td>
</tr>
<tr>
<td>Direct Instruction</td>
<td>Q: What is an ideal gas?</td>
<td></td>
</tr>
<tr>
<td>Variable Relationships</td>
<td>A: An ideal gas is a hypothetical gas that obeys all the gas laws perfectly under all conditions; that is, it does not condense into a liquid when cooled, and graphs of its</td>
<td></td>
</tr>
</tbody>
</table>
volume and temperature and of its pressure and temperature relationships are perfectly straight lines.

Put up the relationship established by Boyle’s Law, Charles Law, the pressure-temperature law and the volume-mole relationship.

- According to Boyle’s law, the volume of a gas is inversely proportional to the pressure:
  - $v \propto 1/p$
- According to Charles’s law, the volume of a gas is directly proportional to the absolute temperature:
  - $v \propto T$
- According to the pressure–temperature law, the pressure of a gas is directly proportional to the absolute Kelvin temperature:
  - $p \propto T$
- As anyone knows who has blown up a balloon, the more air you blow into the balloon, the bigger it gets; in other words, the greater the amount of air, in moles, at the same temperature and pressure, the greater the volume, Avogadro’s Principle:
  - $v \propto n$

Q: What relationships have a common variable?

A: $v \propto 1/p \quad v \propto T \quad v \propto n$

Q: Combine these three relationships into just one relationship for volume

A: $v \propto 1/p \times T \times n$

Q: How do we remove a proportion and create a formula or equation with an equal sign?

A: Need a constant, gas constant ($R$).

Show

$V = nRT / P$, then explain when variables are directly proportional they are found on opposite sides of the equal sign, when they are inversely proportional they are found on the same side of the equal sign (or as a denominator on the opposite side).

Q: Knowing this and that $p \propto T$, how can we rewrite the equation?

A: $PV = nRT$ (Ideal Gas Law)

<table>
<thead>
<tr>
<th>Activity 1</th>
<th>Group Exploration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STP</strong></td>
<td><strong>STP – Standard Temperature and Pressure</strong></td>
</tr>
<tr>
<td></td>
<td>$T = 0^\circ C \text{ or } 273 \text{ K}$</td>
</tr>
<tr>
<td></td>
<td>$P = 1 \text{ atm or } 760 \text{ mmHg}$</td>
</tr>
<tr>
<td></td>
<td>The volume of 1 mole of gas at STP is called the <strong>molar volume</strong> and has a value of approximately 22.4 L.</td>
</tr>
<tr>
<td>Q: Use the Ideal Gas Law to show that this is true. Solve for Volume of 1 mol of gas using STP and the gas constant.</td>
<td></td>
</tr>
<tr>
<td>A: $V = nRT / P = (1 \text{ mol})(0.08206 \text{ L atm} / \text{mol-K})(273 \text{ K}) / (1 \text{ atm}) = 22.40 \text{ L}$</td>
<td></td>
</tr>
<tr>
<td><strong>Groups of 4</strong>: Visualization of the molar volume of gas</td>
<td></td>
</tr>
<tr>
<td>Q: Convert 22.4 L into cubic centimetres.</td>
<td>~ 30 min</td>
</tr>
</tbody>
</table>
A: $22.4 \text{ L} \times 1000 \text{ mL} / \text{ L} = 22400 \text{ mL}$

$1 \text{ mL} = 1 \text{ cm}^3 \rightarrow 22400 \text{ cm}^3$

Have the students construct a box with the cardboard with the correct dimensions to create a box with a cubic volume of $22400 \text{ cm}^3$ (sides = 28.2 cm)

Compare the box to other household items: Basketballs, Soccer balls, Pop bottles, Orange Juice jugs etc. However, make sure to indicate that the pressure of the air in the sports equipment is higher than 1 atm.

**Groups of 4:** Estimation of the molar volume of a gas

- Measure out a mole of dry ice (44 g) and place it in a clear plastic garbage bag.
- Seal the bag securely with plastic tie, wait for dry ice to sublime (CO$_2$ gas)
- After the dry ice has sublimed allow it to warm to room temperature
- Roll the sealed end of the bag until it reaches the turgid state (no major wrinkles)
- Mark this point on the bag with a piece of tape or marking pen
- Open the bag, put it in a sink and fill the bag with water in 1 L increments

The amount of water it takes to fill the bag to the mark should be roughly 22.4 L. Make a note that room temperature is not STP, but we are close enough to get approximate values.

<table>
<thead>
<tr>
<th>Activity 3</th>
<th>Practice Problems/Homework – Textbook Pg 445: Questions 2, 4, 6, 8 &amp; 10</th>
<th>~ 17 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent work</td>
<td>The students will have the rest of the period to start their homework. If they do not finish the questions they will be required to complete them for homework.</td>
<td></td>
</tr>
</tbody>
</table>

**IV. CONSOLIDATION** *(This consolidates or “firms up” the concepts taught. It wraps up the lesson, allows for class feedback, reviews key concepts and summarizes, confirms learning. This is not the same as application. It is a “wrap up” or a “what did we learn” component. Puts closure to the lesson.)*

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Timing</th>
</tr>
</thead>
</table>
| Take up first homework question | **Question 2, pg 445**

**Q:** Under what conditions is a gas closest to the properties of an ideal gas? Why?

**A:** A gas that obeyed the ideal gas equation exactly under any conditions would be an ideal gas, but no actual gas perfectly conforms to the equation at all temperatures and pressures. Under the conditions of high temperatures and low pressures present over much of Earth’s surface, however, most real gases behave as ideal gases. Gases with boiling points below $–173^\circ\text{C}$ ($-279^\circ\text{F}$), such as hydrogen, oxygen, nitrogen, and the noble gases, come closest to being ideal gases. Gases with relatively high boiling points, such as carbon dioxide, obey the gas laws only approximately. | ~ 5 min |
5. Assessment and Evaluation

(What assessment and/or evaluation strategies do you need to have to ensure you are accountable for students’ learning and addressing the Ontario curriculum expectations? What formative and summative assessment should you include? – e.g., sample questions, activities or attach tests, homework, rubrics, evaluation schemes, answer keys etc.)

Assessment: The students will be assessed based on the questions that they ask and the responses they give during the lesson. When circulating during the exploration activities, the students will be assessed through probing questions. They will also be observed to see how they are working with each other and tackling the exploration activities.

Evaluation: The students will be having their homework marked next class → Pg 445: Questions 2, 4, 6, 8 & 10.

Associate/Advisor Comments:
1. Instructional Expectations and Opportunities

a) Expectations: (approx. 1-3 expectations from the Ontario Curriculum that could be assessed)

SCH 3U Grade 11 University Chemistry – Gas and Atmospheric Chemistry

*Developing Skills of Investigation and Communication*

- F2.4 use stoichiometry to solve problems related to chemical reactions involving gases (e.g., problems involving moles, number of atoms, number of molecules, mass, and volume) [AI]

b) Opportunities: (approx. 2+ other learning opportunities such as other expectations not assessed, other learning that happens as a result of the lesson e.g., organization, group, listening, co-operation, reading, writing skills etc.)

Opportunity to review the following from previous strands:

SCH 3U Grade 11 University Chemistry – Quantities in Chemical Reactions

*Developing Skills of Investigation and Communication*

- D2.3 solve problems related to quantities in chemical reactions by performing calculations involving quantities in moles, number of particles, and atomic mass [AI]

*Understanding Basic Concepts*

- D3.4 explain the quantitative relationships expressed in a balanced chemical equation, using appropriate units of measure (e.g., moles, grams, atoms, ions, molecules)

- Reintroduce and expand “stoichiometry roadmap” and “mole bridge” that would have been introduced in the strand Quantities in Chemical Reactions

Associate/Advisor Comments:

2. Pre-assessment and Accommodations/Modifications

a) Students

(consider the students you will be teaching and anything that will affect their learning or your teaching strategies (e.g., include academic, behavioural & social/emotional, physical and diversity needs, + provide accommodations/modifications - how you will differentiate learning for each student and/or type of need – N.B. use initials of students rather than full names)

<table>
<thead>
<tr>
<th>Pre-assessment:</th>
<th>Accommodation/Modification:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior Knowledge:</td>
<td></td>
</tr>
<tr>
<td>1) This lesson is presented near the end of the unit on Gas Laws and Atmospheric Chemistry. In previous lessons in this unit students would have learned about Gas Laws (e.g. Boyle’s Law, Charles’ Law, Ideal Gas Law, etc.), Avogadro’s hypothesis and molar volume</td>
<td></td>
</tr>
<tr>
<td>2) Students would have encountered stoichiometry problems in previous strands in this course (e.g. Quantities in Chemical Reactions and Solutions and Solubility). This strand takes stoichiometry further to include the use of the ideal gas law in reactions involving gases</td>
<td></td>
</tr>
</tbody>
</table>
3) Students should be familiar with the concept of the mole, molar mass, Avogadro’s number, “mole bridge”, “stoichiometry roadmap” (concepts that would have been introduced in previous strands)

Academic Needs
1) Some students will still be having difficulty with stoichiometry problems, even though they have been covered in 2 previous strands in the course. The teacher may have to review the basics of stoichiometry problems for these students (e.g. reviewing how to make conversions from moles → mass)

b) Learning Environment:
(describe the learning environment such as the set up/location of desks, where audio-visual equipment will be, where the teacher stands, where the students are working etc. – you may wish to include a map/layout of the classroom on a separate sheet and reference it with modifications if lesson changes)

Students will be seated at their lab benches while the concept map and note are being put on the board and during their individual work on the stoichiometry assignment. Teacher will be at the front of the class at the chalkboard during the lecture/note-taking. Teacher will be circulating while students are working on stoichiometry assignment at their desk and providing assistance as required.

Associate/Advisor Comments:

### 3. Required Resources

(list ALL resources required to conduct this lesson with detailed specifics such as textbook titles, chapters, page numbers, author/publishers, website URLs, resources like paper, pencils, protractors, chalk, rulers, paint, specimens, books, maps, videos, posters, lab materials, handouts – include name of handout and number of copies, etc.)

**Student Resources:**
- Pen/pencil/eraser/lined paper
- Calculator
- Chemistry Notebook (including notes from other strands in case they need them for to review how to complete stoichiometry problems)
- Stoichiometry Concept Map Note from Units on Solids and Liquids
Teacher Resources
- Stoichiometry Concept Map for Gases – to be put up board for students to copy down
  o http://www.ugdsb.on.ca/ccvisci/SCH3U1ma/MoleSum.pdf
- Enough copies of Gas Stoichiometry Assignments for all students in the class
- Gas Stoichiometry examples to be put up on board and discussed with class
  o http://www.magma.ca/~dougdela/ideas/4-stoich.pdf
  o http://www.archbishopjordan.ab.ca/Science%20Notes/chemistry%2020/Chem%2020%20Unit%2007%20Overhead%20Notes_Gases.doc
  o http://www.ugdsb.on.ca/ccvisci/sch3umat.htm
- Chalk/Chalkboard
- Pringle Can Demo http://educ.queensu.ca/~science/main/concept/gen/g09/E.%20Kiepek/pringlescan.html
  o 1 Pringle Can
  o Matches
  o Hydrogen cylinder
  o Scotch tape
  o Ring stand
  o Small diameter iron ring
  o Hammer and nail
  o Wooden splint

4. Content and Teaching Strategies of Lesson

a) Overview/Agenda/Review
(consider a quick overview of the lesson and/or list key elements in lesson which may be written on white/blackboard as an agenda for students and you to follow, you may also choose to consider a review of previous day’s work)

1) Exploding Pringle Can Demo
2) Teacher Directed Lecture – Gas Stoichiometry (Stoichiometry Concept Map and Examples using the ideal gas law)
3) Practice – Students will have the remainder of the period (and next class) to work on Gas Stoichiometry Assignment

b) Subject Content and Teaching Strategies (This section includes the details of the lesson’s subject content and how this content will be organized and implemented for student learning)

I. SUBJECT CONTENT (only list content related material – NOT how you will teach it; this section is a reference section for you, the teacher or anyone else who uses your lesson plan, regarding content; might include diagrams, facts, maps, definitions, terminology, examples, anything that may be necessary for you to understand to address students’ questions, extend their thinking or scaffold learning;)

<table>
<thead>
<tr>
<th>Content Name</th>
<th>Content Details</th>
</tr>
</thead>
</table>
| Gas Stoichiometry     | Way of accurately calculating exact quantities of reactants and products in a chemical reaction  
Refer to “Stoichiometry Road Map”  
General steps of the stoichiometry calculation are the same for both solids and gases. Mass \rightarrow Moles use molar mass; volume \rightarrow moles use molar volume. Molar mass depends on chemical involved (e.g. different for each chemical), but molar volume of gas depends only on temperature and pressure. If conditions are not standard (e.g. STP or SATP), then use the ideal gas law (PV=nRT) rather than the molar volume to find the amount or volume of a gas |
II. INTRODUCTION (motivational start, minds-on, hook, etc.) (describe how you will motivate students, get their attention, relate the lesson to their lives, such as a minds-on activity, a hook or an activity that will pull learners into lesson – ensure you provide a step-by-step description of this introduction with an approximate timing)

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Timing</th>
</tr>
</thead>
</table>

1. Distribute the POE handout. Describe what you intend to do.
   a. If the Pringles can is not empty, distribute the chips among the students to empty the can.
   b. Using the hammer and nail, make a small hole (~1mm) in the centre of the metal end of the can.
   c. Cover the hole with a piece of scotch tape. Fold the end of the tape over so it can be easily removed later.
   d. Using a knife, cut a hole approximately 5 mm in diameter in the centre of the plastic lid.
   e. Attach the iron ring to the ring stand and place the Pringles can on the ring stand, lid down. Make sure there are no lights directly overhead.
   f. Using the hydrogen cylinder, fill the Pringles can with hydrogen through the hole in the lid. The pitch of the hydrogen rushing into the can will change when the can is full of hydrogen. **IMPORTANT:** If the can is not completely filled with hydrogen, there is the possibility that it will explode immediately when it is lit.

2. Have the students make predictions (with justification) about what will happen if the tape is removed from the small hole on the metal end of the can and a flame is brought near the hole.

3. Light the wooden flint.

4. Remove the tape from the small hole on the metal end of the can and bring the burning splint over the hole.

5. Have the students make observations. (i.e. nothing seemed to happen.)

6. Turn out all the lights. A thin blue flame should be visible above the hole.

7. Ask the students for explanations for what they observe.

8. Within 2 or 3 minutes (depending on the size of the small hole), the students should be able to hear a high-pitched whine emanating from the Pringles can.

9. After about 15 seconds the can will explode and shoot up to the ceiling.

10. Have students explain why the can exploded.
III. **INSTRUCTION** (this details how you will organize the content for student learning; include strategies and EXACT sequence of instruction; similar to a script—your statements, actions, students’ actions, transitions, distribution of material, guiding questions AND students’ anticipated responses; include sufficient white space for easy reference; include approximate timing) AND

**APPLICATION** (How will the students apply their new learning? This typically follows Instruction BUT it could be incorporated as part of the Instruction. Examples include role playing the parts of a cell, solving problems, worksheet, labelling a diagram, making a model, creating a mind-map, etc.)

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Timing</th>
</tr>
</thead>
</table>
| Lecture – Note-taking and Examples | **Lecture and Note on Gas Stoichiometry**  
This is the third time that students will have encountered stoichiometry in this course. First they learned how to do mole ↔ mass stoichiometry and then they learned solution stoichiometry (concentration ↔ moles). Now, they will be learning stoichiometry for gases by using gas volume, molar volume and the ideal gas law in stoichiometry equations.  
1. In the solids unit where students first were introduced to stoichiometry they started a note/concept map on stoichiometry (refer to stoichiometry concept map – note). In the next unit on solutions, they added to the concept map for solution stoichiometry. Now, students will add to the concept map for gases.  
2. Teacher will ask students to take out stoichiometry concept map from their notes and state that we will be finishing the concept map this period.  
3. Students will add the concept of molar volume (e.g. gas volume at STP, SATP) to their concept map – this was taught in a previous lesson.  
4. Next, teacher will show how to solve a stoichiometry involving volume at STP (SATP) using the “Talk Aloud” teaching strategy and the “up, over and down” method of solving stoichiometry problems.  
“In previous lesson on stoichiometry, we learned the steps of solving a stoichiometry problem. Let’s try one involving molar volume at STP.”  
Teacher shows the following problem on the overhead and asks students to copy it into their notes:  
“If 275 g of propane burns in a gas barbecue, what volume of oxygen measured at STP is required for the reaction?”  
Q. What is the first step to solving this problem?  
A. To write the balanced chemical equation for the reaction.  
“Correct. The balance chemical equation for this reaction is:  
\[ \text{C}_3\text{H}_8(g) + 5 \text{O}_2(g) \rightarrow 3 \text{CO}_2(g) + 4 \text{H}_2\text{O}(g) \]  
Q. What is the next step in solving the problem?  
A. List the given and the required measurements and the conversion factors for each chemical.  
Q. What is that information from the question above?  
\[ \text{C}_3\text{H}_8 + 5 \text{O}_2 \rightarrow 3 \text{CO}_2 + 4 \text{H}_2\text{O} \]  
\[ 275g \ v=? \]  
Q. What is the next step?  
A. Convert the given measurement to moles using the appropriate conversion | 30-40 min |
factor.

“Right. So if we look at our concept map, we are given the mass of \( C_3H_8 \) and we want to convert mass to moles, so divide the given mass by its molar mass to find the number of moles of propane.”

\[
\frac{m}{M} = \frac{275g}{44.11 \text{ g/mol}}
\]

\[
n_{C_3H_8} = 6.23 \text{ mol}
\]

\[
C_3H_8 + 5 O_2 \rightarrow 3 CO_2 + 4 H_2O
\]

\[
6.23 \text{ mol} \rightarrow 44.11 \text{ g/mol}
\]

\[
\frac{275g}{22.4 \text{ L/mol}}
\]

Q. “Now that we have the molecules of \( C_3H_8 \), now what do we do?”

A. Use the stoichiometric ratio to find the number of moles of \( O_2 \).

“So looking at the balanced chemical equation we see that the stoichiometric ratio is \( 5 \text{ mol } O_2/1 \text{ mol } C_3H_8 \). To find the moles of \( O_2 \) we do the following:

\[
n_{O_2} = \frac{6.23 \text{ mol } C_3H_8 \times 5 \text{ mol } O_2}{1 \text{ mol } C_3H_8}
\]

\[
n_{O_2} = 31.2 \text{ mol}
\]

\[
C_3H_8 + 5 O_2 \rightarrow 3 CO_2 + 4 H_2O
\]

\[
6.23 \text{ mol} \rightarrow 31.2 \text{ mol}
\]

\[
\frac{44.11 \text{ g/mol}}{22.4 \text{ L/mol }}
\]

\[
\frac{275g}{698 \text{ L}}
\]

Q. Now that we have the moles of \( O_2 \) needed for the reaction, we need to convert the number of moles of \( O_2 \) into the volume of \( O_2 \) required. How do we do this?

A. Use the molar volume to convert the number of moles of \( O_2 \) into the volume required for the reaction. Look at the stoichiometry concept map if needed.

\[
v_{O_2} = \frac{31.2 \text{ mol } O_2 \times 22.4 \text{ L/mol } O_2}{22.4 \text{ L/mol } O_2}
\]

\[
v_{O_2} = 698 \text{ L}
\]

Therefore, the volume of \( O_2 \) required for the reaction to burn 275 g of propane is 698 L.

5. “All reactions involving gases do not occur at standard conditions (e.g. at STP or SATP). In these cases, instead of using the molar volume, we use the ideal gas law \( \text{PV=nRT} \) to find the unknown volume of gas in a chemical reaction. Let’s add this to our concept map. (see progression of concept map notes, attached). Let’s do an example.”

Students will write this example in their books as the teacher talks them through it.

“What volume of \( CO_{2(g)} \) is produced at 94.5 kPa and 115.5 °C in the exhaust of a car if 100 g of gasoline \( (C_8H_{18(g)}) \) are burned?”

First, let’s write the balanced chemical equation for the reactions:

\[
2C_8H_{18(l)} + 25 O_2(g) \rightarrow 16 CO_{2(g)} + 8 H_2O(g)
\]

Next, we’ll write down all the given and required information underneath the balanced chemical equation.

\[
2C_8H_{18(l)} + 25 O_2(g) \rightarrow 16 CO_{2(g)} + 8 H_2O(g)
\]
100g  

v=?

P= 94.5 kPa

T= 115.5°C = 388.7K

“Now, we start with the information we are given for the substance for which we are not trying to solve any information for, and convert it into moles. So, this where we go **UP**, and use the appropriate conversion factor. In this case, we need the molar mass of gasoline (114.26 g/mol).

\[
2C_8H_{18(g)} + 25 O_{2(g)} \rightarrow 16 CO_{2(g)} + 8 H_2O_{(g)}
\]

\[
0.875 \text{ mol}
\]

\[
114.26 \text{ g/mol} \uparrow \text{UP} \quad 100g \quad v=\
\]

P= 94.5 kPa

T= 115.5°C = 388.7K

To calculate the number of moles, we do the following calculation:

\[
n_{C_8H_{18}} = \frac{100g}{114.26 \text{ g/mol}} = 0.875 \text{ mol}
\]

Now that we know the moles of our given substance, using the stoichiometric ratio, we can calculate the moles of our required substance. So first we went **UP** now we go **OVER**.

\[
2C_8H_{18(g)} \rightarrow 16 CO_{2(g)} + 8 H_2O_{(g)}
\]

\[
0.875 \text{ mol} \rightarrow 7.00 \text{ mol}
\]

\[
114.26 \text{ g/mol} \uparrow \text{UP} \quad \text{OVER} \quad 100g \quad v=\
\]

P= 94.5 kPa

T= 115.5°C = 388.7K

This was calculated by using the stoichiometric ratio:

\[
n_{CO_2} = \frac{0.875 \text{ mol} C_8H_{18}}{2 \text{ mol of } CO_2} \times 16 \text{ mol of } CO_2
\]

\[
n_{CO_2} = 7.00 \text{ mol of } CO_2
\]

So we have gone **UP** and **OVER**, now we go **DOWN** to find the required volume of CO2 formed by the reaction.

\[
2C_8H_{18(g)} + 25 O_{2(g)} \rightarrow 16 CO_{2(g)} + 8 H_2O_{(g)}
\]

\[
0.875 \text{ mol} \rightarrow 7.00 \text{ mol}
\]

\[
114.26 \text{ g/mol} \uparrow \text{UP} \quad \text{OVER} \quad D \quad \text{V = nRT/P} \quad O \quad v=\
\]

P= 94.5 kPa

T= 115.5°C = 388.7K

To calculate the volume of CO2 formed we use the ideal gas law:

\[
V = \frac{nRT}{P}
\]

\[
V_{CO_2} = \frac{(7.00 \text{ mol of } CO_2) (8.314 \text{ kPa}L/mol-K)(388.7K)}{(94.5 \text{ kPa})}
\]

\[
V_{CO_2} = 239 \text{ L}
\]

The volume of CO2 produced is 239 L when 100g of gasoline is burned in the exhaust of a car.
6. Other examples will also be done. They are listed as follows – statements that would be given to students are not included.

**How many moles of sodium must react with H₂O(l) to produce 250 mL of H₂(g) at 23.6 °C and 102.6 kPa?**

\[
2 \text{Na(s)} + 2 \text{HOH(l)} \rightarrow \text{H₂(g)} + 2 \text{NaOH(aq)}
\]

\[
n? = \frac{\text{PV}}{\text{RT}}
\]

\[
n\text{H₂} = \frac{(102.6 \text{ kPa})(0.250 \text{L})}{(8.314 \text{ kPa} \cdot \text{L/mol} \cdot \text{K})(296.8 \text{ K})}
\]

\[
n\text{H₂} = 0.0104 \text{ mol}
\]

\[
2 \text{Na(s)} + 2 \text{HOH(l)} \rightarrow \text{H₂(g)} + 2 \text{NaOH(aq)}
\]

\[
n\text{Na} = 0.0104 \text{ mol} \cdot \frac{\text{H}_2}{2 \text{ mol of Na}} \cdot \frac{1 \text{ mol of H}_2}{2 \text{ mol of Na}}
\]

\[
n\text{Na} = 0.208 \text{ mol}
\]

0.208 mol of Na must react with H₂O to produce 250 mL of H₂ at 23.6°C and 102.6 kPa.

**If 17.8 L of hydrogen, at 22.5 °C and 21.4 kPa, react with nitrogen to produce 22.7 L of ammonia at 33.9 kPa, what’s the temperature of the ammonia (in °C)?**

\[
3 \text{H}_2(g) + \text{N}_2(g) \rightarrow 2 \text{NH}_3(g)
\]

\[
n\text{H}_2 = \frac{\text{PV}}{\text{RT}}
\]

\[
n\text{H}_2 = \frac{(21.4 \text{ kPa})(17.8 \text{L})}{(8.314 \text{ kPa} \cdot \text{L/mol} \cdot \text{K})(295.7 \text{ K})}
\]

\[
n\text{H}_2 = 0.155 \text{ mol}
\]
\[
0.155 \text{ mol } \rightarrow \text{? mol}
\]

\[
\begin{align*}
\uparrow & \quad \downarrow \\
V &= 17.8 \text{ L} & V &= 22.7 \text{ L} \\
T &= 22.5 ^\circ \text{C or 295.7 K} & P &= 33.9 \text{ kPa} \\
P &= 21.4 \text{ kPa} & T &= \text{? } ^\circ \text{C}
\end{align*}
\]

\[
n_{\text{NH}_3} = 0.155 \text{ mol of } \text{H}_2 \times 2 \text{ mol of } \text{NH}_3 \div 3 \text{ mol of } \text{H}_2
\]

\[
n_{\text{NH}_3} = 0.103 \text{ mol}
\]

\[
\begin{align*}
3 \text{ H}_2(\text{g}) & + N_2(\text{g}) \rightarrow 2 \text{ NH}_3(\text{g}) \\
0.155 & \text{ mol} \rightarrow 0.103 \text{ mol} \\
\uparrow & \quad \downarrow \\
V &= 17.8 \text{ L} & V &= 22.7 \text{ L} \\
T &= 22.5 ^\circ \text{C or 295.7 K} & P &= 33.9 \text{ kPa} \\
P &= 21.4 \text{ kPa} & T &= \text{? } ^\circ \text{C}
\end{align*}
\]

\[
T_{\text{NH}_3} = \frac{PV}{nR}
\]

\[
T_{\text{NH}_3} = \frac{[33.9 \text{ kPa}(22.7 \text{ L})]}{[0.103 \text{ mol}](8.314 \text{ kPa·L/mol·K})}
\]

\[
T_{\text{NH}_3} = 896 \text{ K} = 623 ^\circ \text{C}
\]

The temperature of the ammonia is 623°C.

Guided Practice — Gas Stoichiometry Assignment

Students will be given the remainder of the period (and the next class) to work on the Stoichiometry Assignment (see attached).

Teacher will explain the marking scheme to the class for the assignment. Most of the marks for each question are allocated to the steps involved in solving the problem. For instance, 1 mark will be given for showing the steps of UP, DOWN and OVER. Another mark will be given for showing your conversions to moles, etc.

Teacher will circulate the class making sure that students stay on task and answer questions as needed.

IV. CONSOLIDATION (This consolidates or “firms up” the concepts taught. It wraps up the lesson, allows for class feedback, reviews key concepts and summarizes, confirms learning. This is not the same as application. It is a “wrap up” or a “what did we learn” component. Puts closure to the lesson.)

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrap-up</td>
<td>Reminder to students that the next class will be a work period for them to complete the Stoichiometry Assignment for to do the pre-lab calculations for the next lab (the class following the work period). Stoichiometry assignments are to be handed in the day of the lab (e.g. the assignment is for homework if it is not completed during the work period).</td>
<td>2-3 min</td>
</tr>
</tbody>
</table>
5. Assessment and Evaluation

(What assessment and/or evaluation strategies do you need to have to ensure you are accountable for students’ learning and addressing the Ontario curriculum expectations? What formative and summative assessment should you include? – e.g., sample questions, activities or attach tests, homework, rubrics, evaluation schemes, answer keys etc.)

Assessment – Assess students understanding of process of solving stoichiometry problems during Socratic dialogue between student and teacher during development of concept map and gas stoichiometry examples that are done on the board

Evaluation – Evaluate students understanding of solving gas stoichiometry assignment by having students hand-in assignment to be marked the day class after the work period (2 lessons from now)

Assess/Evaluate – Quiz students on before Investigation 10.4.1 on gas stoichiometry problems

| Associate/Advisor Comments: |

---
# The Incredible Pringles Can

<table>
<thead>
<tr>
<th><strong>Prediction</strong></th>
<th><strong>Explanations</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw the experimental setup and make a prediction about what will happen when a flame is brought near the small hole on the top of the can.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Observations</strong></th>
<th><strong>Explanations</strong></th>
</tr>
</thead>
</table>
N_A = Avogadro's Number; M = molar mass

# of molecules, \( N \)

\[ n = \frac{N}{N_A} \]

\[ N = nN_A \]

Moles X, \( n \) → Equations factor → Moles Y, \( n \)

M = nM

\[ n = \frac{m}{M} \]

mass, \( m \)
Stoichiometry Concept Map

\[ N_A = \text{Avogadro's Number}; \quad M = \text{molar mass}; \quad C = \text{molar concentration} \]

\[
\begin{align*}
N &= \frac{n}{N_A} \\
N &= nN_A \\
M &= \frac{m}{n} \quad \text{(mass, } m) \\
n &= \frac{m}{M} \\
\text{Solution Volume, } v &= \frac{n}{C} \\
v &= \frac{n}{Cv}
\end{align*}
\]
Stoichiometry Concept Map

\[ N_A = \text{Avogadro's Number}; M = \text{molar mass}; C = \text{molar concentration} \]

\[ \text{Solution Volume, } v = n/C \]
\[ v = n/C \]
\[ n = N/N_A \]
\[ N = nN_A \]
\[ \text{Moles X, } n \]

\[ \text{Gas Volume @ STP, } v \]
\[ v = nC \]
\[ n = N/N_A \]
\[ N = nN_A \]

\[ X = 22.4 \text{L/mol (24.8)} \]
\[ \div 22.4 \text{L/mol (24.8)} \]

\[ \text{Moles Y, } n \]
\[ m = nM \]
\[ n = m/M \]

\[ \text{mass, } m \]
Stoichiometry Concept Map

\( N_A = \) Avogadro's Number; \( M = \) molar mass; \( C = \) molar concentration

Solution

Volume, \( v \)

\[ v = \frac{n}{C} \]

\[ n = Cv \]

Moles X, \( n \)

\[ n = \frac{N}{N_A} \]

\[ N = nN_A \]

\[ \text{Moles Y, } n \]

\[ m = nM \]

\[ n = \frac{m}{M} \]

\[ v = \frac{PV}{RT} \]

\[ V = \frac{nRT}{P} \]

Gas Volume

@ STP, \( v \)

(SATP)

\[ v = \frac{n}{22.4} \]

\[ v = \frac{n}{22.4} \]

\[ n = \frac{Pv}{RT} \]

\[ V = \frac{nRT}{P} \]

Gas volume, \( v \) @ TP

(not STP or SATP)

\[ v = \frac{n}{22.4} \]

\[ v = \frac{n}{22.4} \]
Gas Stoichiometry Assignment

1. What volume of oxygen gas (at STP) is produced by the decomposition of 100.0 g of sodium nitrate?

\[ 2 \text{NaNO}_3(s) \rightarrow 2 \text{NaO}_2(S) + \text{O}_2(g) \]

2. Glucose is used as an energy source by the human body. The overall reaction in the body is:

\[ \text{C}_6\text{H}_{12}\text{O}_6(aq) + 6 \text{O}_2(g) \rightarrow 6 \text{CO}_2(g) + 5 \text{H}_2\text{O}(l) \]

Calculate the volume of oxygen at STP required to convert 28.0 g of glucose to carbon dioxide and water.

3. When sodium chloride is heated to 800°C it can be electrolytically decomposed into sodium metal & chlorine (Cl₂) gas. What volume of chlorine gas is produced (at 800°C and 100 kPa) if 105 g of Na is also produced?

4. Air bags are activated by a severe impact which causes a detonator to spark the decomposition of sodium azide according to the following reaction:

\[ 2 \text{NaN}_3(s) \rightarrow 2 \text{Na}(s) + 3 \text{N}_2(g) \]

What mass of NaN₃(s) must be reacted to inflate an air bag to 70.0 L at STP?

   a) What volume of O₂ at SATP will be required to react completely with all of the CH₄?
   b) How many grams of H₂O are produced?
   c) What volume of CO₂ (at STP) is produced if only 2.15 g of the CH₄ was burned?

6. The balanced equation below is the reaction between gasoline (octane) and oxygen that occurs inside automobile engines:

\[ 2 \text{C}_8\text{H}_{18(l)} + 25 \text{O}_2(g) \rightarrow 16 \text{CO}_2(g) + 18 \text{H}_2\text{O}(g) \]

   a) If 4.00 moles of gasoline are burned, what volume of oxygen is needed if the pressure is 0.953 atm and the temperature is 35.0°C?
   b) How many grams of water would be produced if 20.0 L of oxygen were burned at a temperature of -10.0°C and a pressure of 1.3 atm?
Gas Stoichiometry Assignment

c) If you burned one gallon of gas (≈ 4000 g), how many litres of carbon dioxide would be produced at a temperature of 21°C and a pressure of 1.00 atm?
d) How many litres of oxygen would be needed to produce 45.0 L of carbon dioxide if the temperature and pressure for both are 0°C and 5.02 atm?

7. Nitroglycerin explodes according to:
\[4 \text{C}_3\text{H}_5(\text{NO}_3)_3(\text{l}) \rightarrow 12 \text{CO}_2(\text{g}) + 6 \text{N}_2(\text{g}) + 10 \text{H}_2\text{O}(\text{g}) + \text{O}_2(\text{g})\]

\(\text{a)}\) Calculate the volume, at STP, of each product formed by the reaction of 100 g of \(\text{C}_3\text{H}_5(\text{NO}_3)_3\)

\(\text{b)}\) 200 g of \(\text{C}_3\text{H}_5(\text{NO}_3)_3\) is ignited (and completely decomposes) in an otherwise empty 50 L gas cylinder. What will the pressure in the cylinder be if the temperature stabilizes at 220°C?

Total: \(\text{/70}\)
Gas Stoichiometry Assignment - ANSWERS

1. What volume of oxygen gas (at STP) is produced by the decomposition of 100.0 g of sodium nitrate? (5 marks)

\[ 2 \text{NaNO}_3(\text{s}) \rightarrow 2 \text{NaO}_2(\text{s}) + \text{O}_2(\text{g}) \]

\[ \frac{100 \text{g}}{85.1 \text{g/mol}} = 1.18 \text{mol} \quad (1\text{mark}) \]

\[ \text{NO}_2 = 1.18 \text{mol} \cdot \frac{1 \text{mol} \cdot \text{O}_2}{2 \text{mol} \cdot \text{NaNO}_3} \]

\[ \text{NO}_2 = 0.588 \text{mol} \quad (1\text{mark}) \]

\[ \text{Vo}_2 = 0.588 \text{mol} \cdot 22.4 \text{L/mol} \]

\[ \text{Vo}_2 = 13.2 \text{L} \quad (1\text{mark}) \]

\[ \rightarrow \text{volume of O}_2 \text{ produced at STP is } 13.2 \text{L} \quad (1\text{mark}) \]

2. Glucose is used as an energy source by the human body. The overall reaction in the body is:

\[ \text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) + 6 \text{O}_2(\text{g}) \rightarrow 6 \text{CO}_2(\text{g}) + 5 \text{H}_2\text{O}(\text{l}) \]

Calculate the volume of oxygen at STP required to convert 28.0 g of glucose to carbon dioxide and water. (5 marks)

\[ \text{glucose} = \frac{28.0 \text{g}}{180.15 \text{g/mol}} \]

\[ = 0.155 \text{mol} \quad (1\text{mark}) \]

\[ \frac{0.155 \text{mol}}{6 \text{mol} \cdot \text{O}_2} \]

\[ = 0.0258 \text{mol} \cdot \text{O}_2 \quad (1\text{mark}) \]

\[ \text{Vo}_2 = 0.0258 \text{mol} \cdot 22.4 \text{L/mol} \]

\[ \text{Vo}_2 = 0.932 \text{L} \quad (1\text{mark}) \]

\[ \rightarrow \text{volume of O}_2 \text{ produced at STP is } 20.92 \text{L} \quad (1\text{mark}) \]

Page 1 of 7
Gas and Atmospheric Chemistry | SCH 3U
3. When sodium chloride is heated to 800°C it can be electrolytically decomposed into sodium metal & chlorine (Cl₂) gas. What volume of chlorine gas is produced (at 800°C and 100 kPa) if 105 g of Na is also produced? (5 marks)

\[ 2 \text{NaCl} \rightarrow 2 \text{Na} + \text{Cl}_2 \]

- \( \text{NaCl} \): 105 g
- \( \text{NaCl} \): 23 g/mol
- \( \text{NaCl} \): 4.57 mol (1 mark)
- \( \text{Cl}_2 \): 2.83 mol (1 mark)
- \( \text{Cl}_2 \): 2 mol of Na
- \( V_{\text{Cl}_2} = \frac{nRT}{P} \)
- \( V_{\text{Cl}_2} = \frac{(2.83 \text{ mol})(8.314)(1073 \text{ K})}{100 \text{ kPa}} \)
- \( V_{\text{Cl}_2} = 204 \text{ L} \) (1 mark)

4. Air bags are activated by a severe impact which causes a detonator to spark the decomposition of sodium azide according to the following reaction:

\[ 2 \text{NaN}_3(s) \rightarrow 2 \text{Na}(s) + 3 \text{N}_2(g) \]

What mass of NaN₃(s) must be reacted to inflate an air bag to 70.0 L at STP?

- \( \text{N}_2 \): 70.0 L
- \( \text{N}_2 \): 22.4 L/mol
- \( \text{N}_2 \): 3.125 mol (1 mark)
- \( \text{NaN}_3 \): 3.125 mol of Na × 2 mol NaN₃
- \( \text{NaN}_3 \): 3 mol of NaN₃
- \( \text{NaN}_3 \): 2.08 mol (4 mark)
- \( m \text{NaN}_3 \): 2.08 mol × 65.01 g/mol
- \( m \text{NaN}_3 \): 135 g (4 mark)

(1 mark) If NaN₃(s) must be reacted to inflate an airbag to 70.0 L at STP.

a) What volume of O₂ at SATP will be required to react completely with all of the CH₄?

\[ \frac{PV}{RT} = \frac{0.167 \text{ mol} \times 328 \text{ kPa} \times 1 \text{ L}}{8.314 \text{ J/mol K} \times 288 \text{ K}} = 0.167 \text{ mol of CH}_4 \]

\[ V = \frac{nRT}{P} = \frac{0.167 \text{ mol} \times 0.082057 \text{ L atm/mol K} \times 288 \text{ K}}{328 \text{ kPa}} = 0.122 \text{ L} \]

b) How many grams of H₂O are produced?

\[ 1 \text{ mol of CH}_4 \rightarrow 1 \text{ mol of H}_2 \text{O} \]

\[ n_{\text{H}_2\text{O}} = 0.334 \text{ mol} \times \frac{2}{1} = 0.668 \text{ mol} \]

\[ m_{\text{H}_2\text{O}} = 0.668 \text{ mol} \times 18.02 \text{ g/mol} = 11.99 \text{ g} \]

\[ \therefore 6.01 \text{ g of } H_2O \text{ are produced} \]

c) What volume of CO₂ (at STP) is produced if only 2.15 g of the CH₄ was burned?

\[ n_{\text{CH}_4} = \frac{2.15 \text{ g}}{16.04 \text{ g/mol}} = 0.134 \text{ mol} \]

\[ V_{\text{CO}_2} = 0.134 \text{ mol} \times 22.4 \text{ L/mol} = 2.99 \text{ L} \]

\[ \therefore \text{volume of CO}_2 \text{ produced at STP is 3.01 L} \]
6. The balanced equation below is the reaction between gasoline (octane) and oxygen that occurs inside automobile engines:

\[ 2 \text{C}_8\text{H}_{18(l)} + 25 \text{O}_2(g) \rightarrow 16 \text{CO}_2(g) + 18 \text{H}_2\text{O}_2(g) \]

a) If 4.00 moles of gasoline are burned, what volume of oxygen is needed if the pressure is 0.953 atm and the temperature is 35.0°C?

\[ \text{V}_2 = \frac{nRT}{P} \]

\[ = \left( \frac{4.00 \text{ mol of } \text{C}_8\text{H}_{18}}{1 \text{ mol of } \text{C}_8\text{H}_{18}} \right) \times \frac{25 \text{ mol of } \text{O}_2}{4.00 \text{ mol of } \text{C}_8\text{H}_{18}} \]

\[ = 50.0 \text{ mol of } \text{O}_2 \]

\[ V_2 = \frac{(50.0 \text{ mol})(0.08205)(308 \text{ K})}{0.953 \text{ atm}} \]

\[ = 132.6 \text{ L} \]

Volume of oxygen needed is 132.6 L.

b) How many grams of water would be produced if 20.0 L of oxygen were burned at a temperature of -10.0°C and a pressure of 1.3 atm?

\[ \text{V}_2 = \frac{nRT}{P} \]

\[ = (1.3 \text{ atm})(20 \text{ L}) \]

\[ = (0.08205)(268 \text{ K}) \]

\[ = 1.205 \text{ mol of } \text{O}_2 \]

\[ n_{\text{H}_2\text{O}} = 1.205 \text{ mol of } \text{O}_2 \times 18 \text{ mol of } \text{H}_2\text{O} \]

\[ n_{\text{H}_2\text{O}} = 0.863 \text{ mol of } \text{H}_2\text{O} \]

\[ m_{\text{H}_2\text{O}} = 0.863 \text{ mol} \times 18 \text{ g/mol} = 15.5 \text{ g} \]

15.5 g of water would be produced.
c) If you burned one gallon of gas (≈ 4000 g), how many litres of carbon dioxide would be produced at a temperature of 21°C and a pressure of 1.00 atm?

\[ \text{C}_8\text{H}_{18} = \frac{4000 \text{ g}}{114 \text{ g/mol}} = 35.09 \text{ mol} \]  

\[ 2 \text{C}_8\text{H}_{18} + 25\text{O}_2 \rightarrow 16\text{CO}_2 + 18\text{H}_2\text{O} \]

\[ \text{V} = \frac{nRT}{P} = \frac{(280.72 \text{ mol})(0.08205 \text{ L atm/mol K})(294 \text{ K})}{1.00 \text{ atm}} = \frac{6772.1 \text{ L of CO}_2}{4 \text{ mark}} \]

\[ \text{nCO}_2 = 280.72 \text{ mol} \]

\[ \text{nCO}_2 = 280.72 \text{ mol} \times \frac{114 \text{ g CO}_2}{1 \text{ mol CO}_2} \]

\[ \text{d} \) How many litres of oxygen would be needed to produce 45.0 L of carbon dioxide if the temperature and pressure for both are 0°C and 5.02 atm?

\[ \text{V}_1 = \frac{n_1}{n_2} \]

\[ \text{V}_2 = \frac{n_2}{n_1} \times \text{V}_1 \]

\[ \text{V}_2 = \frac{25 \text{ mol of O}_2}{114 \text{ mol of CO}_2} \times 45.0 \text{ L of CO}_2 = \frac{70.3 \text{ L of O}_2}{1 \text{ mark}} \]
7. Nitroglycerin explodes according to:

\[ 4 \text{C}_3\text{H}_5(\text{NO}_3)_3(\ell) \rightarrow 12 \text{CO}_2(\ell) + 6 \text{N}_2(\ell) + 10 \text{H}_2\text{O}(\ell) + \text{O}_2(\ell) \]

a) Calculate the volume, at STP, of each product formed by the reaction of 100 g of \( \text{C}_3\text{H}_5(\text{NO}_3)_3 \)

\[
4 \text{C}_3\text{H}_5(\text{NO}_3)_3 \rightarrow 12 \text{CO}_2 + 6 \text{N}_2 + 10 \text{H}_2\text{O} + \text{O}_2
\]

\[
\text{molar mass of C}_3\text{H}_5(\text{NO}_3)_3 = 227.11 \text{g/mol}
\]

\[
\text{mol of C}_3\text{H}_5(\text{NO}_3)_3 = \frac{100 \text{g}}{227.11 \text{g/mol}} = 0.4403 \text{mol (3 marks)}
\]

\[
\text{mol of CO}_2 = 0.4403 \text{mol} \times \frac{12 \text{mol CO}_2}{4 \text{mol C}_3\text{H}_5(\text{NO}_3)_3} = 1.3209 \text{mol} \times 22.41 \text{L/mol} = 29.6 \text{L (2 marks)}
\]

\[
\text{mol of N}_2 = 0.4403 \text{mol} \times \frac{6 \text{mol N}_2}{4 \text{mol C}_3\text{H}_5(\text{NO}_3)_3} = 0.6605 \text{mol} \times 22.41 \text{L/mol} = 14.8 \text{L (2 marks)}
\]

\[
\text{mol of H}_2\text{O} = 0.4403 \text{mol} \times \frac{10 \text{mol H}_2\text{O}}{4 \text{mol C}_3\text{H}_5(\text{NO}_3)_3} = 1.1008 \text{mol} \times 22.41 \text{L/mol} = 24.7 \text{L (2 marks)}
\]

\[
\text{mol of O}_2 = 0.1104 \text{mol} \times 22.41 \text{L/mol} = 2.47 \text{L (2 marks)}
\]

Volume of each product produced is:

- 29.6 L of CO₂
- 24.7 L of H₂O
- 14.8 L of N₂
- 2.47 L of O₂ (4 marks)

Page 6 of 7
Gas and Atmospheric Chemistry | SCH 3U
b) 200 g of $C_3H_5(NO_3)_3$ is ignited (and completely decomposes) in an otherwise empty 50 L gas cylinder. What will the pressure in the cylinder be if the temperature stabilizes at 220°C?

$$C_3H_5(NO_3)_3 \rightarrow 12O_2 + 6N_2 + 10H_2O + O_2$$

0.881 mol → # moles for all gases

\[ \text{200g} \]  
\[ \text{50 L} \]  
\[ T = 220^\circ C \]  
\[ P = ? \]

(1 mark)

\[ \text{Pressure in the cylinder will be} \]  
\[ 523 \text{ kPa} \]  

(4 mark)