Atmospheric Composition, Layers, and Pressure

Goals: After completing this lab, you will be able to:

- Calculate and summarize permanent and variable atmospheric gases.
- Use steps associated with the scientific method to investigate an atmospheric hypothesis.
- Create and summarize atmospheric graphs illustrating air pressure, temperature, and altitude.
- Identify, use, and interpret different methods of measuring atmospheric pressure.

Key Terms and Concepts:

- air pressure
- environmental lapse rate
- hectopascal (hPa)
- kilopascal (kPa)
- mesopause
- mesosphere
- millibar (mb)
- pascal (Pa)
- pounds per square inch (psi)
- stratopause
- stratosphere
- thermosphere
- tropopause
- troposphere

Required Materials:

- Calculator
- Textbook: *Living Physical Geography*, by Bruce Gervais

Problem-Solving Module #1: Atmospheric Composition

1. The total mass of Earth's atmosphere is 5.6 x 10^{15} kg. Complete Table 1–1. *Hint: See Section 1.1 in textbook.*

Permanent Atmospheric Gas	Percent of Atmosphere	Total Mass (kg) (Scientific Notation)	Total Mass (kg) (Nonscientific Notation)
Nitrogen (N_2)	78%		
Oxygen (O_2)	21%		
Argon (Ar)	1%		

TABLE 1–1

2. Water vapor is a variable gas, meaning the amount that is in the atmosphere changes. Depending on the season, latitude and local conditions, water vapor may constitute up to what percentage of our atmospheric gas?

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Permanent & Variable Atmospheric Gases	Percent of Atmosphere (0% H_2O)	Percent of Atmosphere (1% H_2O)	Percent of Atmosphere (2% H_2O)	Percent of Atmosphere (3% H_2O)	Percent of Atmosphere (4% H_2O)
N_2	78%	77%	76%	76%	75%
O_2	21%	21%	21%	20%	20%
Ar	1%	1%	1%	1%	1%
H_2O	0%	1%	2%	3%	4%

TABLE 1–2

3. According to Table 1–2, what happens to the percentage of nitrogen and oxygen in the atmosphere as the percentage of water vapor increases?

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An atom's "atomic mass number" is the number of protons and neutrons within its nucleus. For example, the most common form of nitrogen has an atomic mass number of 14 because it has 7 protons and 7 neutrons within its nucleus (7 + 7 = 14). The most common form of oxygen has an atomic mass number of 16 because it has 8 protons and 8 neutrons within its nucleus (8 + 8 = 16). The mass of any electron is so small that it is not factored into determining an atom's atomic mass number.

A subscript is the little number to the lower right of each letter. Subscripts tell us how many atoms of a particular element are present in a molecule. For example, when you breathe in oxygen (O), you are actually inhaling oxygen molecules (O_2), and each oxygen molecule is composed of two atoms. When you breathe in nitrogen (N), you are actually inhaling nitrogen molecules (N_2), and each nitrogen molecule is composed of two atoms.

Because a single oxygen atom (O) has an atomic mass number of 16, a single oxygen molecule (O_2) has a molecular mass of 32 (16 + 16 = 32). Similarly, because a single nitrogen atom (N) has an atomic mass number of 14, a single nitrogen molecule (N_2) has a molecular mass of 28 (14 + 14 = 28).

4. Complete Table 1–3.

Element	Atomic Mass Number (protons + neutrons)	Atmospheric Gas Formula	Atmospheric Gas Mass
N	14	N_2	
O	16	O_2	32
Ar	40	Ar	
H	1	H_2O	

TABLE 1–3

Suppose someone claims that air with a large percentage of water vapor has less mass than air with a small percentage of water vapor. This sounds strange to you (and possibly wrong) because humid air simply *feels* heavier compared to dry air. You decide to test this claim using the scientific method.

5. In your own words, compose a hypothesis about the mass of humid air versus dry air.

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6. To test your hypothesis, what data would you need to collect?

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7. Use the data in Tables 1–2 and 1–3 to complete Figure 1–1.

1,000 Molecule Sample of Moist Air (4% H_2O)

Number of N_2 molecules: ______

Number of O_2 molecules: ______

Number of Ar molecules: __10__

Number of H_2O molecules: __40__

Mass of all N_2 molecules: __21,000__

Mass of all O_2 molecules: ______

Mass of all Ar molecules: ______

Mass of all H_2O molecules: ______

Mass of all molecules: ______

1,000 Molecule Sample of Dry Air (1% H_2O)

Number of N_2 molecules: ______

Number of O_2 molecules: ______

Number of Ar molecules: __10__

Number of H_2O molecules: __10__

Mass of all N_2 molecules: ______

Mass of all O_2 molecules: __6,720__

Mass of all Ar molecules: ______

Mass of all H_2O molecules: ______

Mass of all molecules: ______

FIGURE 1–1

8. Explain why your hypothesis is supported or not supported by the data presented in Figure 1–1.

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9. In your own words, compose a sentence or two that corresponds with Step #6 of the scientific method as it relates to the mass of humid air versus dry air.

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Problem-Solving Module #2: Atmospheric Layers, Temperatures, and Lapse Rates

1. Create a line graph on Figure 2–1 (on the following page) by plotting the data presented in Table 2–1.

Elevation (km)	Temperature (°C)
0	18
11	–58
20	–58
32	–45
50	0
53	0
80	–90
85	–90
100	–70
120	80

TABLE 2–1

2. Complete Table 2–2 using the graph you created on Figure 2–1.

Elevation Range (km)	Temperature Trend (Increases, Decreases, Remains Constant)
0–11	
11–20	
20–50	
50–53	
53–80	
80–85	
85–120	

TABLE 2–2

3. Label the four layers of the atmosphere on the lines provided on the right side of Figure 2–1. *Hint: See textbook, Section 1.3.*

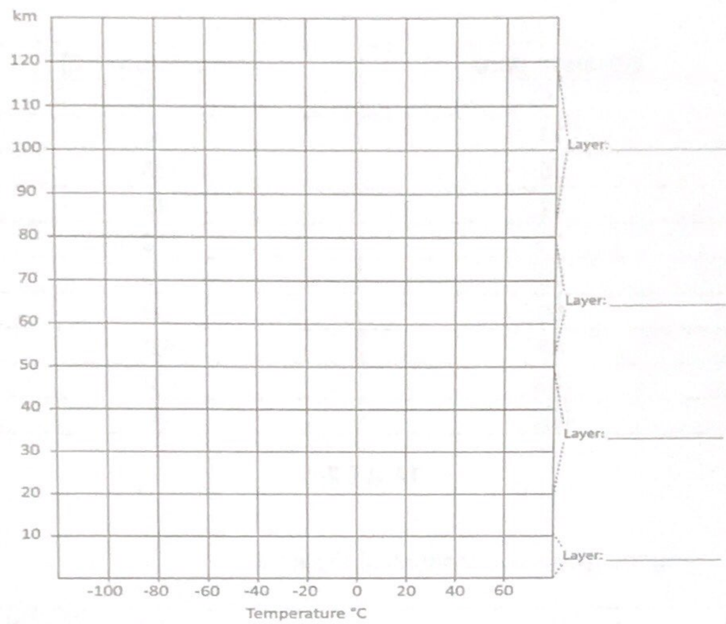

FIGURE 2–1

4. Complete Table 2–3:
   Hints:
   - *Range is the total number of units separating two values.*
   - *Obtain temperatures from your work on Figure 2–2.*
   - *Calculate environmental lapse rate by dividing temperature range by elevation range.*

	Elevations (km)	Elevation Range (km)	Temperatures (°C)	Temperature Range (°C)	Environmental Lapse Rate °C/km
Layer 1	0–11	11	18 to –58		
Layer 2	11–50			58	
Layer 3	50–80	30	0 to –90		3
Layer 4	80–120				

TABLE 2–3

5. In all the above work, it is assumed that Layer 1 of the atmosphere ends at 11 km above Earth's surface—an elevation called the tropopause. Explain why the height of the tropopause varies.

Reason #1: ____

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Reason #2: ____

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Problem-Solving Module #3: Atmospheric Pressure

Elevation (km)	Millibar (mbar)	Hectopascal (hPa)	Kilopascal (kPa)	Pounds per square inch (psi)	Inches of Mercury (inHg)
0	1013.25	1013.25	101.325	14.69	29.92
1	878.36	878.36	87.836	12.73	25.93
2	761.43	761.43	76.143	11.04	22.48
3	660.07	660.07	66.007	9.57	19.49
4	572.20	572.20	57.220	8.29	16.89
5	496.02	496.02	49.602	7.19	14.64
6	429.99	429.99	42.999	6.23	12.69
7	372.75	372.75	37.275	5.40	11.00
8	323.13	323.13	32.313	4.68	9.54
9	280.11	280.11	28.011	4.06	8.27
10	242.82	242.82	24.282	3.52	7.17
15	118.87	118.87	11.887	1.72	3.51
20	58.19	58.19	5.819	0.84	1.71
30	13.94	13.94	1.394	0.20	0.41
40	3.34	3.34	.334	0.04	0.09
50	0.80	0.80	.080	0.01	0.02

TABLE 3–1

1. Table 3–1 presents five different ways to express average atmospheric station pressure. Examine the millibar and hectopascal values. What is unique about the values in both of these columns?

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2. Compare the hectopascal values to the kilopascal values. What is the difference, why does it occur, and how do units of 100 versus 1,000 fit into your answer?

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3. Guayaquil, Ecuador is about 10 meters above sea level. If you inflated a balloon in Guayaquil, about how much atmosphere, in pounds per square inch, would press on the outside of your balloon?

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4. Assume you took your inflated and sealed balloon up to Quito, Ecuador, which is about 2,850 meters above sea level. Roughly estimate about how much atmosphere, in pounds per square inch, would now press on the outside of your balloon.

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5. Predict what would happen to the diameter of your balloon as you drove from Guayaquil to Quito, and why.

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Barometers record higher pressure when more air molecules are present at a recording station. They record lower pressure when fewer air molecules are present at a recording station. Early barometers recorded air pressure with mercury (Hg) held within an inverted glass cylinder that was itself held within a pool of Hg. The cylinder was sealed at its top and marked in hundredths of inches. The mercury would rise when more air molecules were present and fall when fewer air molecules were present.

6. Table 3–1 illustrates that as elevation _______________, inches of mercury (inHg) __________.
(increases/decreases) (increases/decreases)

Atmospheric pressure constantly changes as weather systems move through an area (this is studied in a later lab). For questions 7–9 (below), however, assume that weather is held constant and is thus not an issue for consideration at this time.

7. Which of the four locations in Figure 3–1 is located nearest to sea level, and how do you know this?

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8. Which of the four locations in Figure 3–1 is located at the highest elevation, and how do you know this?

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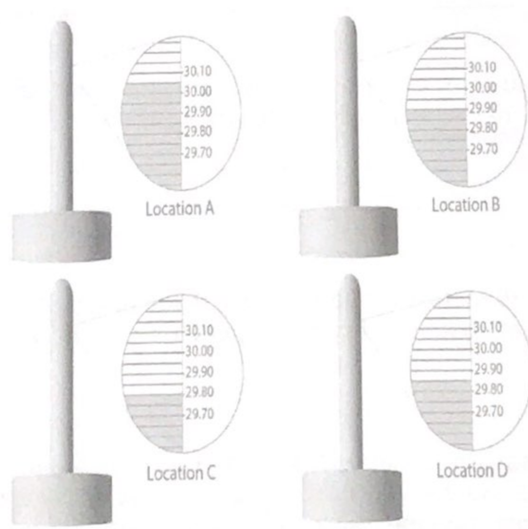

FIGURE 3–1

9. Rank the weather stations in Table 3–2 according to their elevation, with #1 located nearest to sea level. Determine their relative elevations using the data presented in Table 3–1.

Location	inHg	Elevation Rank: 1, 2, 3, 4, or 5 (#1 = nearest to sea level) (#5 = farthest from sea level)
Weather station A	30.71	
Weather station B	30.05	
Weather station C	29.97	
Weather station D	30.52	
Weather station E	30.12	

TABLE 3–2

10. Create a line graph on Figure 3–2 by plotting the data presented in Table 3–1.

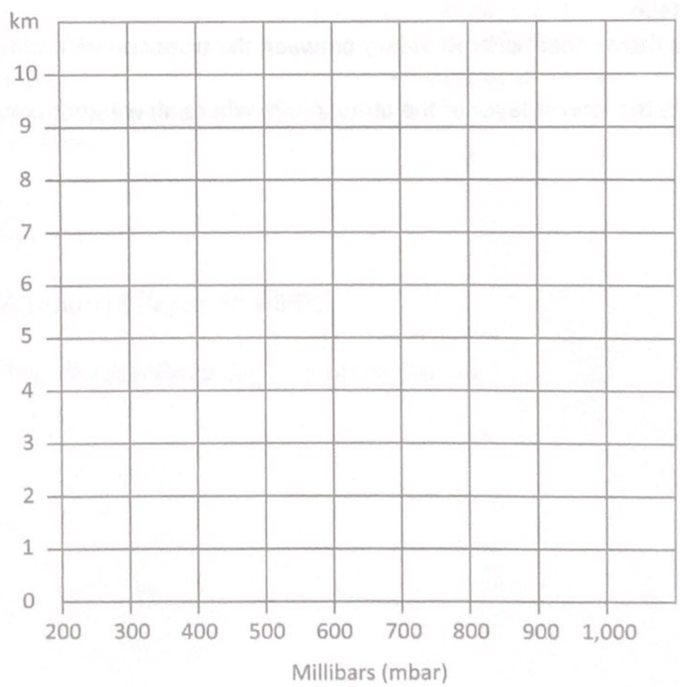

FIGURE 3–2

11. The peak of Mount Everest is 8,848 meters. According to Figure 3–2, what is the predicted average air pressure at its peak?

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12. Denver, Colorado is 1,600 meters above sea level. According to Figure 3–2, what is the predicted average air pressure in this city?

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Summary of Key Terms and Concepts:

- Air pressure is the force exerted by molecules of air against a surface caused by the weight of air above.
- The environmental lapse rate is the average rate of cooling with altitude in the troposphere (6.5°C per 1,000 meters or 3.6°F per 1,000 feet).
- The following units are commonly used to record and communicate atmospheric pressure: pounds per square inch (psi), pascal (Pa), hectopascal (hPa), kilopascal (kPa), millibar (mb).
- The mesopause is the atmospheric boundary between the mesosphere and thermosphere.
- The mesosphere is the layer of the atmosphere between 50 and 80 km (30 and 50 mi) above Earth's surface.
- The stratopause is the atmospheric boundary between the stratosphere and mesosphere.
- The stratosphere is the atmospheric layer above the troposphere. The stratosphere has a permanent temperature inversion and contains the ozonosphere.
- The thermosphere is the atmospheric layer located from 80 to 600 km (50 to 370 mi) above Earth's surface.
- The tropopause is the atmospheric boundary between the troposphere and the stratosphere.
- The troposphere is the lowest layer of the atmosphere where all weather occurs.