**Key**

**HOMEWORK for Chapter 11: Gases**

**11.3 – 11.7 The Gas Laws** (Read pgs. 332 - 347 in the chemistry textbook)

1. What are the ***name*** of the ***5 Gas laws*** to be learned in this section? What gas properties are covered by

 each law? What gas properties are held constant for each law?

 **NAME of LAW GAS PROPERTIES CONSTANTS**

1. **Boyle’s Law Pressure (P) and Volume (V) T, n**
2. **Charles’s Law Temperature (T) and Volume (V) P, n**
3. **Gay-Lussac’s Law Temperature (T) and Pressure (P) V, n**
4. **Combined Gas Law Pressure, Volume, and Temperature n**
5. **Avogadro’s Law Amount (n) and Volume (V) T, P**
6. What are the mathematical equations and relationships for each gas law?

 **LAW EQUATION RELATIONSHIP**

1. **Boyle’s Law V1** $× $ **P1 = V2** $×$ **P2 INVERSE**
2. **Charles’s Law** $\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{2}} $ **DIRECT**
3. **Gay-Lussac’s Law** $\frac{P\_{1}}{T\_{1}}$ **=** $\frac{P\_{2}}{T\_{2}} $ **DIRECT**
4. **Combined Gas Law** $\frac{V\_{1}P\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}P\_{2}}{T\_{2}}$ **BOTH**
5. **Avogadro’s Law** $\frac{V\_{1}}{n\_{1}}$ **=** $\frac{V\_{2}}{n\_{2}} $ **DIRECT**

3. What do the gas laws help us determine for any given sample of gas?

**REMEMBER! For each law it is assumed that the other gas properties DO NOT CHANGE**

**LAW EXPLANATION**

 **Boyle’s ΔP if the volume changes, or ΔV if the**

 **pressure changes**

 **Charles’s ΔT if the volume changes, or ΔV if the**

 **temperature changes**

 **Gay-Lussac’s ΔP if the temperature changes, or ΔT if the**

 **pressure changes**

 **Combined change in any 1 variable if the other 2 change**

 **Avogadro’s ΔV if the amount changes, or Δn if the**

 **volume changes**



5. (a) Which picture above represents ***Charles’s Law***?  **C**

1. What 2 things are changing? **V and T**
2. What 2 things remain constant? **P and n**

 (b) Which picture above represents ***Boyle’s Law***? **A**

1. What 2 things are changing? **V and P**
2. What 2 things remain constant? **T and n**

 (c) Which picture above represents ***Gay-Lussac’s Law***? **B.**

1. What 2 things are changing? **V and P**
2. What 2 things remain constant? **T and n**

***Questions about BOYLE’S LAW***

1. State and explain (in terms of KMT) the reason for the change (increase, decrease) in a gas that occurs in

 each of the following when ***n*** and ***T*** do not change.

 **VOLUME PRESSURE EXPLANATION**

1. Decreases **INCREASES gas particles collide more often**

 **with sides of container**

1. Increases **DECREASES gas particles collide less often**

 **with sides of container**

5. Use ***Boyle’s Law*** to explain why suba divers need to exhale air when they ascend to the surface of the water.

 **As the diver ascends the pressure is decreasing – therefore, the air in their lungs will expand – and could potentially damage the lungs.**

6. Use ***Boyle’s Law*** to explain why does a sealed bag of chips expands when you take it to a higher altitude?

  **At higher altitudes the atmospheric pressure decreases until it is less than the pressure inside the bag. At that point the air inside the bag is able to “push back” against the pressure of the atmosphere and expands.**



7. Use ***Boyle’s Law*** to explain the condition of the pressurized suit worn by each astronaut above.

**Left: atmospheric pressure on the suit increased – volume of gas in the suit decreased**

**Middle: atmospheric pressure on suit = pressure inside suite - volume is unchanged**

**Right: atmospheric pressure on the suit decreased - volume of gas in the suit has increased**

***Use the diagram below to answer Question 8.***



 **Initial → A or B**

8. The air in a cylinder with a piston has a volume of 220. mL and a presure of 650. mmHg.

1. If a change results in a higher pressure inside the cylinder, does cylinder A or B represent the final volume? Explain your choice.

**A : according to Boyle’s Law as pressure increases volume must**

 **decrease**

1. If the pressure inside the cylinder increases 1.20 atm, what is the final volume, in mL, of the cylinder? Complete the following table.

**Property Conditions 1 Conditions 2 Know Predict**

**Pressure (P) 650. mmHg 1.20 atm P ↑**

**Volume (V) 220. mL *x*  V↓**

**Step 1: convert 1.20 atm to mmHg (or vice-versa)**

 **1.20 atm (** $\frac{760 mmHg}{1 atm}$ **) = 912 mmHg**

**Step 2: Use Boyle’s Law**

 **V1** $× $ **P1 = V2** $×$ **P2 → (220 mL)(650 mmHg) = (912 mmHg) *x***

 ***→ 156.798 = 157 mL***

******

 **C**

9. A balloon is filled with helium gas. When the following changes are made at constant temperature, which

 of these diagrams (A, B, or C) shows the new volume of the balloon?

**C.**

 \_\_\_\_\_\_\_\_\_\_ (a) The balloon floats to ahigher altitude where the outside pressure is lower.

**B.**

 \_\_\_\_\_\_\_\_\_\_ (b) The balloon is taken inside the house, but the atmospheric pressure remains the same.

**A.**

 \_\_\_\_\_\_\_\_\_\_ (c) The balloon is put in a hyperbaric chamber in which the pressure is increased.

10. A gas with a volume of 4.0 Lis in a closed container. Indicate the changes in its pressure when the volume

 undergoes the following changes at constant temperature:

**pressure doubles**

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (a) The volume is compressed to 2.0 L.

**V1** $× $ **P1 = V2** $×$ **P2 → (4.0 L)(1) = (2.0 L) *x → 2 = pressure doubles***

**pressure ↓ by ⅔**

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (b) The volume is allowed to exand to 12 L.

**V1** $× $ **P1 = V2** $×$ **P2 → (4.0 L)(1) = (12.0 L) *x → 0.33 = pressure ↓ to a ⅓ of original***

**pressure ↑ by 10**

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (c) The volume is compressed to 0.40 L.

**V1** $× $ **P1 = V2** $×$ **P2 → (4.0 L)(1) = (0.40 L) *x → 10. = pressure ↑ by factor of 10***

11. A gas at a pressure of 2.0 atm is in a closed container. Indicate the changes in its volume whenthe

 pressure undergoes the following changes at constant

**volume ↓ by ⅔**

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (a) The pressure is increased to 6.0 atm.

**V1** $× $ **P1 = V2** $×$ **P2 → (2.0 atm)(1) = (6.0 atm) *x → 0.33 = volume↓ to a ⅓ of original***

**volume doubles**

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (b) The pressure drops to 1.0 atm.

**V1** $× $ **P1 = V2** $×$ **P2 → (2.0 atm)(1) = (1.0 atm) *x → 2 = volume doubles***

**volume ↑ by 10**

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (c) The pressure dorps to 0.40 atm.

**V1** $× $ **P1 = V2** $×$ **P2 → (2.0 atm)(1) = (0.40 atm) *x → 10. = volume↑ by factor of 10***

12. A 10.0-L balloon contains helium gas at a pressure of 655 mmHg. What is the new pressure, in mmHg, of

 the helium gas at teach of the following volumes if there is no change in temperature?

 (a) 20.0 L

**V1** $× $ **P1 = V2** $×$ **P2 → (10.0 L)( 655 mmHg) = (20.0 L) *x → 327.5 → 328 mmHg***

 (b) 13, 800 mL

**V1** $× $ **P1 = V2** $×$ **P2 → (10.0 L)( 655 mmHg) = (13.8 L) *x → 474.6 → 475 mmHg***

 (c) 2.50 L

**V1** $× $ **P1 = V2** $×$ **P2 → (10.0 L)( 655 mmHg) = (2.50 L) *x → 2620 mmHg***

 (d) 1,250 mL

**V1** $× $ **P1 = V2** $×$ **P2 → (10.0 L)( 655 mmHg) = (1.25 L) *x → 5240 mmHg***

13. The air in a 5.00-L tank has a pressure of 1.20 atm. What is the new pressure, in atm, of the air when the

 air is placed in tanks that have the following volumes if there is no change in temperature?

 (a) 1.00 L

**V1** $× $ **P1 = V2** $×$ **P2 → (5.00 L)( 1.20 atm) = (1.00 L) *x → 6.00 atm***

 (b) 750. mL

**V1** $× $ **P1 = V2** $×$ **P2 → (5.00 L)( 1.20 atm) = (0.750 L) *x → 8.00 atm***

 (c) 2500. mL

**V1** $× $ **P1 = V2** $×$ **P2 → (5.00 L)(1.20 atm) = (2.500 L) *x → 2.40 atm***

 (d) 8.0 L

**V1** $× $ **P1 = V2** $×$ **P2 → (5.00 L)(1.20 atm) = (8.0 L) *x → 0.750 atm***

14. Cyclopropane, C3H6, is a general anesthetic. A 5.0-L sample has a pressure of 5.0 atm. What is the volume

 of the anesthetic givento a patient at a pressure of 1.0 atm?

 **V1** $× $ **P1 = V2** $×$ **P2 → (5.0 L)(5.0 atm) = (1.0 atm) *x → 25 L***

15. A tank of oxygen holds 20.0 L of oxygen (O2) at a pressure of 15.0 atm. When the gas is released, it

 provides 300. L of oxygen. What is the pressure of this same gas at a volume of 300. L and constant

 temperature?

 **V1** $× $ **P1 = V2** $×$ **P2 → (20.0 L)(15.0 atm) = (300. L) *x → 1.00 atm***

16. A sample of nitrogen (N2) has a volume of 50.0 L at a pressure of 760. mmHg. What is the volume, in

 liters, of the gas at each of the following pressures if there is no change in temperature?

1. 1500 mmHg

**V1** $× $ **P1 = V2** $×$ **P2 → (50.0 L)( 760. mmHg) = (1500 mmHg ) *x → 25 L***

1. 2.0 atm

**760. mmHg = 1.00 atm**

**V1** $× $ **P1 = V2** $×$ **P2 → (50.0 L)( 1.0 atm) = (2.0 atm) *x → 25 L***

1. 51 kPa

**51 kPa (** $\frac{760 mmHg}{101.325 kPa }$ **) = 383. mmHg**

**V1** $× $ **P1 = V2** $×$ **P2 → (50.0 L)( 760. mmHg) = (383. mmHg) *x → 99 L***

1. 850 torr

**850 torr = 850 mmHg**

**V1** $× $ **P1 = V2** $×$ **P2 → (50.0 L)( 760. mmHg) = (850 mmHg) *x → 45 L***

17. A sample of methane (CH4) has a volume of 25 mL at a pressure of 0.80 atm. What is the volume, in

 liters, of the gas at each of the following pressures if there is no change in temperature?

1. 0.40 atm

**V1** $× $ **P1 = V2** $×$ **P2 → (25 mL)( 0.80 atm) = (0.40 atm) *x → 50. mL***

1. 2.00 atm

**V1** $× $ **P1 = V2** $×$ **P2 → (25 mL)( 0.80 atm) = (2.00 atm) *x → 10. m L***

1. 2500 mmHg

**2500 mmHg (** $\frac{1 atm}{760 mmHg }$ **) = 3.3 atm**

**V1** $× $ **P1 = V2** $×$ **P2 → (25 mL)( 0.80 atm) = (3.3 atm) *x → 6.1 mL***

1. 80.0 torr

**80.0 torr (** $\frac{1 atm}{760 torr }$ **) = 0.11 atm**

**V1** $× $ **P1 = V2** $×$ **P2 → (25 mL)( 0.80 atm) = (0.11 atm) *x → 180 mL***

***Questions about Charles’s Law***

18. Select the diagram that shows the new volume of a balloon when the following changes are made at

 constant pressure.

 **C**

**C.**

 \_\_\_\_\_\_\_\_\_\_ (a) The temperature is changed from 100 K to 300 K

**A.**

 \_\_\_\_\_\_\_\_\_\_ (b) The balloon is placed in a freezer.

**B.**

 \_\_\_\_\_\_\_\_\_ (c) The balloon is first warmed, and then returned to its starting temperature.

19. Indicate whether the final volume of gas in each of the following is the same, lager, or smaller than the

 initial volume.

**larger than**

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (a) A volume of 505 mL of air on a cold winter day at ─ 5oC is breathed

 **If T↑ then V↑** into the lungs, where body temperature is 37oC.

**smaller than**

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (b) The heater used to heat 1400 L of air in a hot-air balloon is turned off.

 **If T↓ then V↓**

**larger than**

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (c) A balloon filled with helium at the amusement park is left in a car on

 **If T↑ then V↑** a hot day.

20. A sample of neon initially has a volume of 2.50 L at 15oC. What is the new temperature, in oC, when the

 volume of the sample is changed at consant pressure to each of the following?

 **(a) 5.00 L**

**FIRST: Convert Celsius to Kelvin**

**Convet oC to Kelvin → 15oC + 273 = 288 K**

**SECOND: Use Charles’s Law**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{2.50 L}{288 K}$ **=** $\frac{5.00 L}{x}$ **→ 576 Kelvin**

**THIRD: Convert Kelvin back ot Celsius**

**576 ─ 273 = 303oC**

20. Continued:

 **(b) 1,250 mL**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{2.50 L}{288 K}$ **=** $\frac{1.25 L}{x}$ **→ 144 Kelvin → ─ 129oC**

 **(c) 7.50 L**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{2.50 L}{288 K}$ **=** $\frac{7.50 L}{x}$ **→ 864 Kelvin → 591oC**

  **(d) 3,550 mL**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{2.50 L}{288 K}$ **=** $\frac{3.55 L}{x}$ **→ 409 Kelvin → 136oC**

21. A gas has a volume of 4.00 L at 0oC. What final temperature, in oC, is needed to cause the volume of the

 gas to change to the following, if *n* and P are not changed?

 **(a) 100. L**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{4.00 L}{273 K}$ **=** $\frac{100. L}{x}$ **→ 6830 Kelvin → 6550 oC**

 **(b) 1,200 mL**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{4.00 L}{273 K}$ **=** $\frac{1.2 L}{x}$ **→ 82 Kelvin → ─ 191oC**

 **(c) 250 L**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{4.00 L}{273 K}$ **=** $\frac{2.5 L}{x}$ **→ 170 Kelvin → ─ 103oC**

  **(d) 50.0 mL**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{4.00 L}{273 K}$ **=** $\frac{0.0500 L}{x}$ **→ 3.41 Kelvin → ─ 270.oC**

22. A balloon contains 2500 mL of helium gas at 75oC. What is the new volume, in mL, of the gas when the

 temnperature changes to the following, if n and P are not changed.

 **(a) 55oC**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{2500 m L}{348 K}$ **=** $\frac{ x}{328 K}$ **→ 2400 mL**

 **(b) 680. K**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{2500 m L}{348 K}$ **=** $\frac{x}{680.K}$ **→ 4900 mL**

1. **─ 25oC**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{2500 m L}{348 K}$**=** $\frac{x}{248 K}$ **→ 1800 mL**

  **(d) 240. K**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{2500 m L}{348 K}$**=** $\frac{x}{240.K}$ **→ 1700 mL**

23. An air bubble has a volume of 0.500 L at 18oC. If the pressure does not change, what is the volume, in

 liters, at each of the following temperatures?

 **(a) 0oC**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{0.500 L}{291 K}$ **=** $\frac{ x}{273 K}$ **→ 0.469 L**

 **(b) 427 K**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{0.500 L}{291 K}$ **=** $\frac{x}{427 K}$ **→ 0.734 L**

**(c) ─ 12oC**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{0.500 L}{291 K}$**=** $\frac{x}{261 K}$ **→ 0.448 L**

  **(d) 575 K**

$\frac{V\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}}{T\_{1}}$ **→** $\frac{0.500 L}{291 K}$**=** $\frac{x}{575 K}$ **→ 0.988 L**

***Questions about Gay-Lussac’s Law***

1. (a) What is ***vapor pressure***?

 **the pressure exerted by molecules of a vapor above the surface of**

 **the liquid**

 (b) How is vapor pressure related to temperature?

* **if T↑ than vp ↑**

**b/c more vapor is formed (as long as P = constant)**

* **if T↓ than vp ↓**

**b/c less vapor is formed (as long as P = constant)**

25. How is vapor pressure related to ***boiling point***?

 **bp is when vapor pressure WITHIN a substance = external**

 **pressure**

 **(if the external pressure is atmospheric pressure then the bp will**

 **change with altitude)**

26. Solve for the new pressure, in mmHg, for each of the following with *n* and V constant.

1. A gas with an initial pressure of 1200 torr at 155oC is cooled to 0oC.

**FIRST: Convert Celsius to Kelvin**

**Convet oC to Kelvin → 155oC + 273 = 428 K**

 **0oC + 273 = 273 K**

**SECOND: Convert the pressure units (if needed)**

**Torr = mmHg → 1200 torr = 1200mmHg**

**THIRD: Use Gay-Lussac’s Law**

$\frac{P\_{1}}{T\_{1}}$ **=** $\frac{P\_{2}}{T\_{1}}$ **→** $\frac{1200 mmHg}{428 K}$**=** $\frac{x}{273 K}$ **→ 770 mmHg**

1. A gas in an aerosol can at an initial pressure of 1.40 atm at 12oC is heated to 35oC.

$\frac{P\_{1}}{T\_{1}}$ **=** $\frac{P\_{2}}{T\_{1}}$ **→** $\frac{1064 atm}{285 K}$**=** $\frac{x}{308 K}$ **→ 1150 mmHg**

27. Solve for the new pressure, in atm, for each of the following with *n* and V constant.

1. A gas with an initial pressure of 1.20 atm at 75oC is cooled to ̶ 22oC.

$\frac{P\_{1}}{T\_{1}}$ **=** $\frac{P\_{2}}{T\_{1}}$ **→** $\frac{1.20 atm}{348 K}$ **=** $\frac{x}{251 K}$ **→ 0.866 atm**

1. A sample of N2 with an initial pressure of 780 mmHg at ̶ 75oC is heated to 28oC.

$\frac{P\_{1}}{T\_{1}}$ **=** $\frac{P\_{2}}{T\_{1}}$ **→** $\frac{1.03 atm}{198 K}$**=** $\frac{x}{301 K}$ **→ 1.57 atm**

28. Solve for the new temperature, in oC, for each of the following with *n* and V constant.

1. A sample of xenon at 25oC and 740 mmHg is cooled to give a pressure of 620 mmHg

$\frac{P\_{1}}{T\_{1}}$ **=** $\frac{P\_{2}}{T\_{1}}$ **→** $\frac{740 mmHg}{298 K}$ **=** $\frac{620 mmHg}{x}$ **→ 250.K → ̶ 23oC**

1. A tank of argon gas with a pressure of 0.950 atm at ̶ 18oC is heated to give a pressure of 1250 torr.

$\frac{P\_{1}}{T\_{1}}$ **=** $\frac{P\_{2}}{T\_{1}}$ **→** $\frac{0.950 atm}{255 K}$**=** $\frac{1.64 atm}{x}$ **→ 440. K → 167 oC**

29. Solve for the new temperature, in oC, for each of the following with *n* and V constant.

1. A 10.0-L container of helium gas with a pressure of 250 torr at 0oC is heated to give a pressure of

1500 torr.

$\frac{P\_{1}}{T\_{1}}$ **=** $\frac{P\_{2}}{T\_{1}}$ **→** $\frac{250 torr }{273 K}$ **=** $\frac{1500 torr}{x}$ **→ 1600 K → 1300oC**

1. A 500.0-mL sample of air at 40.oC and 740. mmHg is cooled to give a pressuere of 680. mmHg.

$\frac{P\_{1}}{T\_{1}}$ **=** $\frac{P\_{2}}{T\_{1}}$ **→** $\frac{740. mmHg}{313 K}$**=** $\frac{680. mmHg}{x}$ **→ 288 K → 15 oC**

30. Match the terms vapor pressure, atmophric pressure, and boiling point to the following descriptions.

**boiling point**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (a) the temperature at which bubbles of vapor appear within the liquid

**vapor pressure**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (b) the pressure exerted by a gas above the surface of its liquid

**atmospheric pressure**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (c) the pressure exerted on Earth by the paritcles in the air

**boiling point**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (d) the temperature at which the vapor pressure of a liquid becomes

 equal to the external pressure

31. In which pair(s) of the following list would boiling occur?

 **Atmospheric Pressure Vapor Pressure Boiling? (YES/ NO)**

1. 760 mmHg 700 mmHg **NO**
2. 480 torr 480 mmHg **YES**
3. 1.2 atm 912 mmHg **YES**
4. 1020 mmHg 760 mmHg **NO**
5. 740 torr 1.0 atm **YES**

32. Explain each of the following observations:

1. Water boils at 87oC on the top of Mount Whitney.

**atmospheric pressure decreases with an increase in altitude – a lower temperature will suffice to create a vapor pressure equal to atmospheric pressure**

1. Food cooks more quicly in a pressure cooker than in an open pan.

**as pressure increases the temperature will also increase – food will cook at a higher temperature**

***Questions about the Combined Gas Law***

33. What 3 gas laws are combined to make the combined gas law?

* 1. **Boyle’s Law**
	2. **Charles’s Law**
	3. **Gay-Lussac’s Law**

34. (a) Write the expression for the combined gas law.

$\frac{V\_{1}P\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}P\_{2}}{T\_{2}}$

(b)Rearrange the variables in the combined gas law to solve for each of the following expressions:

1. T2 ***ii.*** P2

 **T2 =** $\frac{T\_{1}V\_{2}P\_{2}}{V\_{1}P\_{1}}$ **P2 =** $\frac{V\_{1}P\_{1}T\_{2}}{V\_{2}T\_{1}}$

35. A sample of helium gas has a volume of 6.50 L at a pressure of 845 mmHg and a temperature of 25oC.

 What is the pressure of the gas, in atm, when the volume and temperature of the gas sample are changed to

 each of the following?

 a) 1850 mL and 325 K

**FIRST: Convert volume units (if needed)**

**1850 mL = 1.85 L**

**SECOND: Convert the pressure units (if needed)**

**845 mmHg = 1.11 atm**

**THIRD: Convert temperature units (if needed)**

**25oC = 298 K**

**FOURTH: Use the Combined Gas Law**

**P2 =** $\frac{V\_{1}P\_{1}T\_{2}}{V\_{2}T\_{1}}$ **→**$ $$\frac{\left(6.50 L\right)\left(1.11 atm\right)(325 K)}{\left(1.85 L\right)(298 K)}$ **= 4.25 atm**

 **V1 = 6.50 L V2 = 1.85 L**

 **P1 = 1.11 atm P2 = X**

 **T1 = 298 K T2 = 325 K**

 b) 2.25 L and 12oC

**P2 =** $\frac{V\_{1}P\_{1}T\_{2}}{V\_{2}T\_{1}}$ **→**$ $$\frac{\left(6.50 L\right)\left(1.11 atm\right)(285 K)}{\left(2.25 L\right)(298 K)}$ **= 3.07 atm**

 **V1 = 6.50 L V2 = 2.25 L**

 **P1 = 1.11 atm P2 = X**

 **T1 = 298 K T2 = 285 K**

 c) 12.8 L and 47oC

**P2 =** $\frac{V\_{1}P\_{1}T\_{2}}{V\_{2}T\_{1}}$ **→**$ $$\frac{\left(6.50 L\right)\left(1.11 atm\right)(320. K)}{\left(12.8 L\right)(298 K)}$ **= 0.605 atm**

 **V1 = 6.50 L V2 = 12.8 L**

 **P1 = 1.11 atm P2 = X**

 **T1 = 298 K T2 = 320. K**

36. A sample of argon gas has a volume of 735 mL at a pressure of 1.20 atm and a temperature of 112oC. What

 is the volume of the gas, in milliliters, when the pressure and temperature of the gas sample are changed to

 each of the following?

$\frac{V\_{1}P\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}P\_{2}}{T\_{2}}$

 a) 658 mmHg and 281 K

**V2 =** $\frac{V\_{1}P\_{1}T\_{2}}{P\_{2}T\_{1}}$ **→**$ $$\frac{\left(735 mL\right)\left(1.20 atm\right)(281 K)}{\left(0.866 atm\right)(385 K)}$ **= 743 mL**

 **V1 = 735 mL V2 = X**

 **P1 = 1.20 atm P2 = 0.866 atm**

 **T1 = 385 K T2 = 281 K**

 b) 0.55 atm and 75oC

**V2 =** $\frac{V\_{1}P\_{1}T\_{2}}{P\_{2}T\_{1}}$ **→**$ $$\frac{\left(735 mL\right)\left(1.20 atm\right)(348 K)}{\left(0.55 atm\right)(385 K)}$ **= 1450 mL**

 **V1 = 735 mL V2 = X**

 **P1 = 1.20 atm P2 = 0.55 atm**

 **T1 = 385 K T2 = 348 K**

 c) 15.4 atm and − 15oC

**V2 =** $\frac{V\_{1}P\_{1}T\_{2}}{P\_{2}T\_{1}}$ **→**$ $$\frac{\left(735 mL\right)\left(1.20 atm\right)(258 K)}{\left(15.4 atm\right)(385 K)}$ **= 38.4 mL**

 **V1 = 735 mL V2 = X**

 **P1 = 1.20 atm P2 = 15.4atm**

 **T1 = 385 K T2 = 258 K**

37. A 124-mL bubble of hot gas initially at 212oC and 1.80 atm is emitted from an active volcano. What is the

 new temperature of the gas, in oC, outside the volcano if the new volume of the bubble is 138 mL and the

 pressure is 0.800 atm?

$\frac{V\_{1}P\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}P\_{2}}{T\_{2}}$

 **T2 =** $\frac{T\_{1}V\_{2}P\_{2}}{V\_{1}P\_{1}}$ **→** $\frac{\left(485 K\right)(138 mL)(0.800 atm)}{\left(124 mL\right)(1.80 atm)}$ **= 240 K → − 33oC**

 **V1 = 124 mL V2 = 138 mL**

 **P1 = 1.80 atm P2 = 0.800 atm**

 **T1 = 485 K T2 = X**

38. A scuba diver 40 ft below the ocean surface inhales 50.0 mL of compressed air mixture in a scuba tank at a

 pressure of 3.00 atm and a temperature of 8oC. What is the pressure , in atm, of air in the lungs if the gas

 expands to 150. mL at a body temperature of 37oC?

$\frac{V\_{1}P\_{1}}{T\_{1}}$ **=** $\frac{V\_{2}P\_{2}}{T\_{2}}$

**P2 =** $\frac{V\_{1}P\_{1}T\_{2}}{V\_{2}T\_{1}}$ **→**$ $$\frac{\left(50.0 mL\right)\left(3.00 atm\right)(310. K)}{\left(150. mL\right)(281 K)}$ **= 12.1 atm**

 **V1 = 50.0 mL V2 = 150. mL**

 **P1 = 3.00 atm P2 = X**

 **T1 = 281 K T2 = 310. K**

***11.7 Questions about the Avogadro's Law***

39. State ***Avogadro’s Law***

**The volume of a gas is directly related to the number of moles of a gas when temperature and pressure are not changed.**

40. What is the ***molar volume*** of a gas?

 **the volume occupied by 1 mole of a gas at STP = 22.4 L**

41. How can the density of any gas be determined at STP?

 **divide the molar mass of the gas by the molar volume at STP**

42. Calculate the densities of each of the following gases in g/ L at STP:

 **Molar**

 **Mass Density**

 (a) F2 **38.00** $\frac{g}{mol}$$\frac{38.00 \frac{g}{mol}}{22.4 \frac{mol}{L}}$ **1.70** $\frac{g}{L}$

 (b) CH4 **16.05** $\frac{g}{mol}$$\frac{16.05 \frac{g}{mol}}{22.4 \frac{mol}{L}}$ **0.717** $\frac{g}{L}$

 (c) Ne **20.18** $\frac{g}{mol}$$\frac{20.18 \frac{g}{mol}}{22.4 \frac{mol}{L}}$ **0.901** $\frac{g}{L}$

 (d) SO2 **64.07** $\frac{g}{mol}$$\frac{64.07 \frac{g}{mol}}{22.4 \frac{mol}{L}}$ **2.86** $\frac{g}{L}$

 (e) C3H8 **40.07** $\frac{g}{mol}$$\frac{40.07 \frac{g}{mol}}{22.4 \frac{mol}{L}}$ **1.79** $\frac{g}{L}$

42. Continued:

 (f) NH3 **17.04** $\frac{g}{mol}$$\frac{17.04 \frac{g}{mol}}{22.4 \frac{mol}{L}}$ **0.761** $\frac{g}{L}$

 (g) Cl2 **70.90** $\frac{g}{mol}$$\frac{70.90 \frac{g}{mol}}{22.4 \frac{mol}{L}}$ **3.17** $\frac{g}{L}$

 (f) Ar **39.95** $\frac{g}{mol}$$\frac{39.95 \frac{g}{mol}}{22.4 \frac{mol}{L}}$ **1.78** $\frac{g}{L}$

43. What happens to the volume of a bicycle tire or a basketball when you use an air pump to add air?

 **if n↑ then V↑ according to Avogadro's law**

44. Sometimes when you blow up a balloon and release it, it flies around the room. What is happening to the

 air that was in the balloon and its volume?

 **n ↓ and V↓**

45. A sample containing 1.50 mol of neon gas has a volume of 8.00 L. What is the new volume of the gas, in

 liters, when the following changes occur in the quantity of gas at constant pressure and temperature?

$\frac{V\_{1}}{n\_{1}}$ **=** $\frac{V\_{2}}{n\_{2}}$

1. A leak allows one half of the neon atoms to escape.

$\frac{V\_{1}}{n\_{1}}$ **=** $\frac{V\_{2}}{n\_{2}}$ **→** $\frac{8.00 L}{1.50 mol}$ **=** $\frac{X}{0.75 mol}$ **→ 4.0 L**

 **V1 = 8.00 L V2 = *X***

 **n1 = 1.50 mol n2 = 0.75 mol**

45. Continued:

1. A sample of 3.50 mol of neon is added to the 1.50 mol of neon gas in the container

$\frac{V\_{1}}{n\_{1}}$ **=** $\frac{V\_{2}}{n\_{2}}$ **→** $\frac{8.00 L}{3.50 mol}$ **=** $\frac{X}{3.50 mol + 1.50 mol}$ **→ 26.7 L**

 **V1 = 8.00 L V2 = *X***

 **n1 = 1.50 mol n2 = 5.00 mol**

1. A sample of 25.0 g if neon is added to the 1.50 mol of neon gas in the container.
2. $\frac{25.0 g Ne}{\frac{20.18 g}{mole}}$ **= 1.24 mol Ne**
3. $\frac{V\_{1}}{n\_{1}}$ **=** $\frac{V\_{2}}{n\_{2}}$ **→** $\frac{8.00 L}{3.50 mol}$ **=** $\frac{X}{1.50 mol + 1.24 mol}$ **→ 14.6 L**

 **V1 = 8.00 L V2 = *X***

 **n1 = 1.50 mol n2 = 2.74 mol**

46. A sample containing 4.80 g of O2 gas has a volume of 15.0 L. Pressure and temperature remain constant.

$\frac{V\_{1}}{n\_{1}}$ **=** $\frac{V\_{2}}{n\_{2}}$

1. $\frac{4.80 g O\_{2}}{\frac{32.00g}{mole}}$ **= 0.150 mol O2**
2. What is the new volume if 0.500 mol of O2 gas is added?

$\frac{V\_{1}}{n\_{1}}$ **=** $\frac{V\_{2}}{n\_{2}}$ **→** $\frac{15.0 L}{0.150 mol}$ **=** $\frac{X}{0.150 mol + 0.500 mol}$ **→ 65.0 L**

 **V1 = 15.0 L V2 = *X***

 **n1 = 0.150 mol n2 = 0.650 mol**

46. Continued:

1. Oxygen is released until the volume is 10.0 L. How many moles of O2 are removed?

$\frac{V\_{1}}{n\_{1}}$ **=** $\frac{V\_{2}}{n\_{2}}$ **→** $\frac{15.0 L}{0.150 mol}$ **=** $\frac{10.0 L}{X}$ **→ 0.100 mol**

 **V1 = 15.0 L V2 = 10.0 L**

 **n1 = 0.150 mol n2 = *X***

47. Use molar volume to solve each of the following at STP:

1. the number of moles of O2 in 44.8 L of O2 gas

$\frac{1 mol O\_{2}}{22.4 L}$$×$ **44.8 L = 2.00 mol of O2**

1. the number of moles of CO2 in 4.00 L of CO2 gas

$\frac{1 mol CO\_{2}}{22.4 L}$$×$ **4.00 L = 0.179 mol of CO2**

1. the volume (L) of 6.40 g of O2
2. $\frac{6.40 g O\_{2}}{32.00 \frac{g}{mol}}$ **= 0.200 mol of O2**
3. **0.200 mol O2** $(22.4 \frac{L}{mole}$**) = 4.48 L**
4. the volume (mL) occupied by 50.0 g of neon
5. $\frac{50.0 g Ne }{20.18 \frac{g}{mol}}$ **= 2.48 mol of Ne**
6. $2.48 mol Ne (22.4 \frac{L}{mole}$**) = 55.5 L → 55,500 mL**

48. Use molar volume to solve each of the following at STP:

1. the volume (L) occupied by 2.50 mol of N2

**2.50 mol Ne** $(22.4 \frac{L}{mole}$**) = 56.0 L**

1. the volume (mL) occupied by 0.420 mol He

 **0.420 mol He** $(22.4 \frac{L}{mole}$**) = 9.408 L → 9, 410 mL**

1. the number of grams of neon contained in 11.2 L of Ne gas.
2. $\frac{1 mol Ne}{22.4 L}$$×$ **11.2 L = 0.500 mol of Ne**
3. **0.500 mol Ne** $(20.18 \frac{g}{mole}$**) = 10.1 g of Ne**
4. the number of moles of H2 in 1620 mL of H2 gas

$ \frac{1 mol H\_{2}}{22.4 L}$$×$ **1.620 L = 0.0723 mol of H2**