Name: _____

Class: _____

Due Date: _____

B.3 Gas Laws

Understandings

- Pressure is given by $P = \frac{F}{A}$ where F is the force exerted perpendicular to the surface.
- The amount of substance n as given by $n = \frac{N}{N_A}$ where N is the number of molecules and N_A is the Avogadro constant.
- Ideal gases are described in terms of the kinetic energy and constitute a modeled system used to approximate the behavior of real gases.
- The ideal gas law equation can be derived from the empirical gas laws for constant pressure, constant volume, and constant temperature as given by $\frac{PV}{T} = \text{constant}$.
- The equations governing the behavior of ideal gases as given by $PV = nk_BT$ and $PV = nRT$.
- The change in momentum of particles due to collisions with a given surface gives rise to pressure in gases and, from that analysis, pressure is related to the average translational speed of molecules as given by $P = \frac{1}{3}\rho v^2$.
- The relationship between the internal energy U of an ideal monatomic gas and the number of molecules or amount of substance as given by $U = \frac{3}{2}Nk_BT$ or $U = \frac{3}{2}RnT$.
- The temperature, pressure, and density conditions under which an ideal gas is a good approximation of a real gas.

Equations

$P = \frac{F}{A}$

$N = \frac{N}{N_{\mathrm{A}}}$

$\frac{PV}{T} = \text{constant}$

$PV = nRT = Nk_{\mathrm{B}}T$

$P = \frac{1}{3}\rho v^2$

$U = \frac{3}{2}nRT = \frac{3}{2}Nk_{\mathrm{B}}T$

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Part 1: Use your favorite sources to answer the following questions

1. C: Define and give the units for each variable for *pressure* $P = \frac{F}{A}$. Is it a scalar or vector? Do not confuse pressure P with power P or momentum $\vec{p}$ or density ρ!

2. E: The surface area of an average human male foot is approximately $651\ \text{cm}^2$. Determine the pressure on each foot of a 75.0 kg man standing on both feet.

3. C: Define *Avogadro's constant* N_A.

4. C: Define and give the units for each variable for a *mole* $n = N/N_A$.

5. E: Determine the number of molecules in 3.25 moles of O_2.

6. E: Determine the number of moles of 1.47×10^{26} particles.

7. E: Consider H_2O.
   a. What is the molar mass of H_2O?

   b. How many moles are in 50.0 grams of H_2O?

   c. How many grams are in 18.0 moles of H_2O?

8. E: Consider CO_2.
   a. What is the molar mass of CO_2?

   b. How many moles are in 26.0 grams of CO_2?

   c. How many grams are in 32 moles of CO_2?

9. E: Consider CH_4.
   a. What is the molar mass of CH_4?

   b. How many moles are in 46.0 grams of CH_4?

   c. How many grams are in 146 moles of CH_4?

10. C: Define and give the units of *atomic mass unit u.*

11.C: State some characteristics of an *ideal gas.*

12.C: What are some differences between an *ideal gas* and a *real gas*?

13.C: Define and draw a graph showing *Boyle's Law.*

14.C: Define and draw a graph showing *Charles' Law.*

15.C: Define and draw a graph showing *Gay-Lussac's Law.*

16. C: Take *Boyle's Law*, *Charles' Law*, and *Gay-Lussac's Law* to obtain a general equation for an ideal gas.

17. C: Define and give the units of each variable for the *Ideal Gas Law* $PV = nRT$.

18. C: Define and give the units of each variable for the *Ideal Gas Law* $PV = Nk_{\mathrm{B}}T$.

19. E: What is the number of moles of an ideal gas in $80.0\ \mathrm{cm}^3$ at room temperature of 20.0°C and a pressure of 1.00×10^5 Pa?

20. E: What is the volume of 22.0 moles of an ideal gas when it fills a cylinder at a temperature of 40.0°C and a pressure of 1.01×10^5 Pa?

21. E: What is the temperature of 0.255 moles of an ideal gas when it fills a volume of $225\ \mathrm{cm}^3$ at a pressure of 1.01×10^5 Pa?

22. E: Three moles of an ideal gas originally occupies a volume of $120.\,\text{cm}^3$ with a pressure of 1.01×10^5 Pa at a temperature of 23.0°C. What will be its new volume if its pressure is held constant and its temperature increases to 35.0°C?

23. E: Five moles of an ideal gas originally occupies a volume of $160.\,\text{cm}^3$ with a pressure of 1.01×10^5 Pa at a temperature of 23.0°C. What will be its new pressure if its volume is held constant and its temperature increases to 75.0°C?

24. E: Two moles of an ideal gas originally occupies a volume of $346.\,\text{cm}^3$ with a pressure of 1.01×10^5 Pa at a temperature of 30.0°C. What will be its new pressure if its volume increases to $362.\,\text{cm}^3$ and its temperature is held constant?

25. C: Define and give the units for each variable for the equation for the kinetic theory of an ideal gas $P = \frac{1}{3}\rho v^2$.

26. E: The density of air on Earth is approximately $1.29\ \frac{\text{kg}}{\text{m}^3}$ at a pressure of 1.01×10^5 Pa. Assume the air is an ideal gas. Determine the average speed of the air.

27. E: The density of air on Mars is approximately $0.200\ \frac{\text{kg}}{\text{m}^3}$ at a pressure of 610 Pa. Assume the air is an ideal gas. Determine the average speed of the air.

28. C: Define and give the units for each variable for the equation for the internal energy of an ideal monatomic gas $U = \frac{3}{2}nRT = \frac{3}{2}Nk_{\text{B}}T$.

29. E: Determine the internal energy of 7.42 moles of an ideal gas at a temperature of 32.0°C.

30. E: Determine the internal energy of 2.84×10^{24} particles of an ideal gas at a temperature of 27.0°C.

31. E: Use the equation $\overline{E_{\text{K}}} = \frac{3}{2}k_{\text{B}}T$ to determine the average kinetic energy and speed of O_2 at a room temperature of 20.0°C. Assume O_2 is an ideal gas.

32.E: Use the equation $\overline{E_{\mathrm{K}}} = \frac{3}{2}k_{\mathrm{B}}T$ to determine the average kinetic energy and speed of $\mathrm{CO_2}$ at a temperature of 23.0°C. Assume $\mathrm{CO_2}$ is an ideal gas.