Announcements for Thursday, 21NOV2024

- Week 12 Homework Assignments available on eLearning
  - Graded and Timed Quiz 11 – "Thermochemistry" due **Monday, 25NOV2024, at 6:00 PM (EST)**
- **Next Week: Changes in Designation of Class Days**
  - There **WILL** be recitations next week
  - Monday, 25NOV2024, is Monday Classes
  - Tuesday, 26NOV2024, is ***Thursday Classes***
  - Wednesday, 27NOV2024, is ***Friday Classes***
- Thanksgiving Break
  - Thursday, 28NOV2024 – Sunday, 01DEC2024
  - No classes for the entire university
- Students requiring **ODS accommodations** for Exam 3 and the Final Exam
  - Monday, 25NOV2024, is the deadline to submit requests for final exams and all remaining exams for the Fall semester

ANY GENERAL QUESTIONS? Feel free to see me after class!

4 Basic Gas Properties

- any gaseous sample can be completely described by giving values for

1. pressure (P)
   - usually in atm, torr, or mmHg
2. volume (V)
   - usually in L or mL
3. amount (n)
   - usually in moles
4. temperature
   - usually in °C but **must** be converted into Kelvin for calculations

★ these properties are interrelated
   - changing one property affects the others

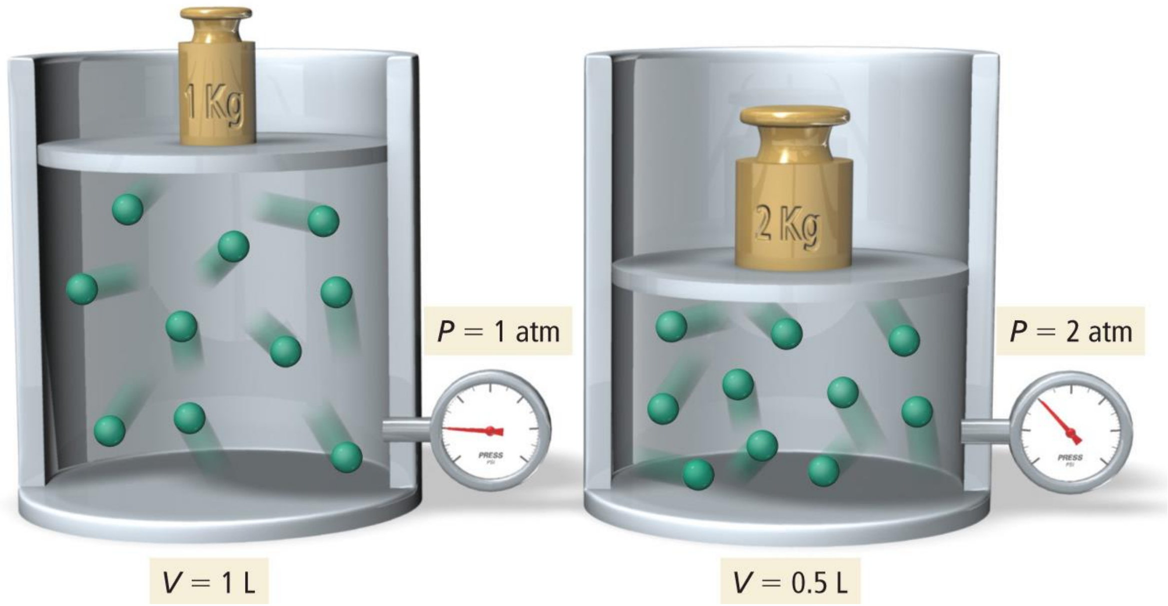
HOW are these properties mathematically related?

Gas Properties: Pressure vs. Volume

- at constant temperature and amount

$$P \propto \frac{1}{V} \text{ (Boyles's law)}$$

- decreased volume = shorter distances travelled by gas particles = more frequent collisions with walls = greater pressure



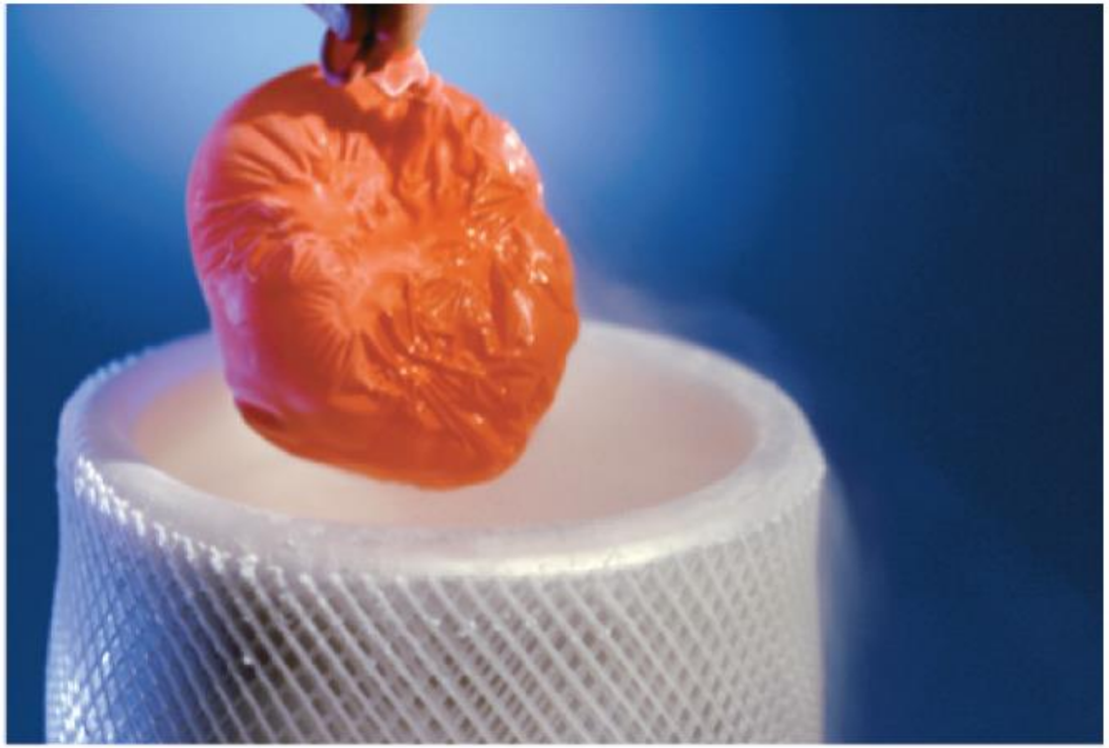
$$P_1V_1 = P_2V_2 \text{ (constant T, n)}$$

Gas Properties: Volume vs. Temperature

- at constant pressure and amount

  $V \propto T$ (Charles's law)

- decreased temperature = slower particles = less frequent collisions with walls = lower pressure would result so volume must contract to keep pressure constant



$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$ (constant P, n)

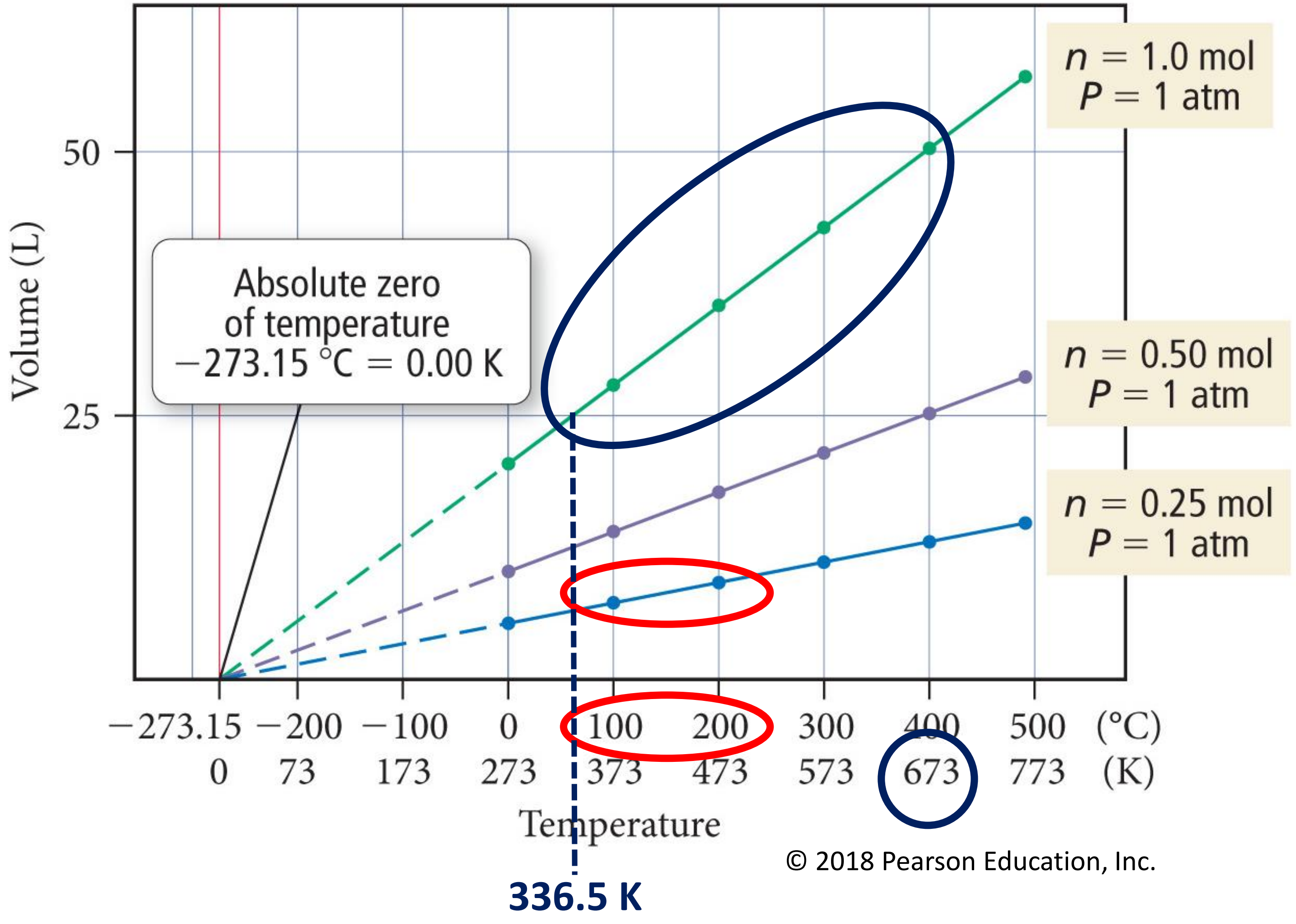
TEMPERATURE MUST BE IN KELVIN!! K = °C + 273.15

Why Kelvin?

V is ***directly proportional*** to T ***only when temperature is in Kelvin***

Doubling T (°C) does NOT double the volume

Doubling T (K) DOES double the volume



Gas Properties: Volume vs. Amount

- at constant pressure and temperature

  $V \propto n$ (Avogadro's law)

- increased amount = more particles to occupy more space = greater volume

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} \text{ (constant P, T)}$$

Gas Properties: Pressure vs. Temperature

- at constant volume and amount

  $P \propto T$ (Amonton's law)

  - book refers to it as Gay-Lussac's law

- increased temperature = faster particles = more frequent collisions with walls = greater pressure

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$ (constant V, n)

TEMPERATURE MUST BE IN KELVIN!! K = °C + 273.15

The Combined Gas Law

- not expressly covered in the book
- the simple gas laws can be combined into one

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}\ (T\ in\ Kelvin)$$

- when properties are constant for a given scenario, they cancel out of the equation to give one of the simpler gas laws

Try These On Your Own

- A deep-sea diver exhales a 15.0-mL bubble of air at a depth where the pressure is 12.0 atm and the temperature is 8.0 °C. What is the volume of the bubble at the surface, where the atmospheric pressure is 770 torr and the temperature is 20.0 °C?

- A sample of gas at 100 °C and 1.05 atm occupies a volume of 825 mL. To what temperature must the gas be brought so that it occupies a volume of 1.50 L at 0.985 atm?

- A 10.00-g sample of CH_4(g) initially at a pressure of 888 Torr and occupying a rigid container with a constant volume is heated from 62 °C to 458 °C. What mass of methane needs to be removed to maintain a constant pressure within the container?

The Ideal Gas Law

recall that $\frac{PV}{nT} =$ constant

when a gas behaves **ideally (?!?)**, this constant has a special name and value

- R = the ideal gas constant
  - really important constant; will be showing up in many equations

$PV = nRT$ (the ideal gas law)

where R =

- 0.08206 L·atm/mol·K
- 8.3145 J/mol·K
- other values possible based on units of V and P

The Ideal Gas Law (continued)

- used to calculate a gas property knowing the other three variables

What volume (in L) is occupied by 2.50 mol He(g) when it is at 298 K and 0.955 atm? Assume ideal behavior.

$$\mathrm{PV = nRT \Rightarrow V = \frac{nRT}{P}}$$

$$\mathrm{V = \frac{(2.50\ mol)\left(0.08206\ \frac{L\cdot atm}{mol\cdot K}\right)(298\ K)}{0.955\ atm} = \mathbf{64.0\ L}}$$

- all the simpler gas laws are contained within PV = nRT
  - don’t memorize them; derive them

Deriving Simple Gas Laws

A sample of an ideal gas is added to a ***rigid*** container at **10. °C** and exerts a pressure of **1.25 atm**. **What is the pressure** of the gas when its **temperature is raised** to **220. °C**?

"***rigid*** container" = constant volume (V)

no mention of gas being added to or removed from container = constant amount (n)

$$PV = nRT$$

constants: V & n

variables: P & T

rearrange PV = nRT getting **constants** on one side and variables on the other

$$\frac{\mathbf{P}}{\mathbf{T}} = \boxed{\frac{\mathbf{nR}}{\mathbf{V}}} \longrightarrow \frac{P_1}{T_1} = \frac{P_2}{T_2} \longrightarrow P_2 = \frac{P_1 T_2}{T_1} = \frac{(1.25\ \mathrm{atm})(220. + 273)\mathrm{K}}{(10. + 273)\mathrm{K}}$$

constant value

Amonton's law

$$= 2.18\ \mathrm{atm}$$

Ideal Behavior for Gases

1. aside from collisions, gas particles behave independently of one another
   - i.e., they don't exert forces over each other
   - this is most true at high temperatures
2. the volume of a gas particles is small compared to the space between them
   - this is most true at low pressures (high container volumes)

- gases behave **most ideally** under low pressure and high temperature
  - when a gas acts ideally, its behavior closely follows the ideal gas law
- gases behave *least ideally* under high pressure and low temperature

Try This

Dry ice is solid carbon dioxide. A 0.050-g sample of dry ice is placed in an evacuated 4.6-L vessel at 31 °C. Calculate the pressure (in torr) inside the vessel after all the dry ice has sublimed to $CO_2(g)$. Assume ideal behavior. 1 atm = 760 torr. **4.7 torr**

sublimation: $CO_2(s) \rightarrow CO_2(g)$

$$\text{moles } CO_2\ (\mathbf{n}) = 0.050 \text{ g } CO_2 \times \frac{1 \text{ mole } CO_2}{44.01 \text{ g}} = 0.001136 \text{ mol}$$

$$\text{volume } CO_2\ (\mathbf{V}) = 4.6 \text{ L}$$

$$\text{temperature } CO_2\ (\mathbf{T}) = 31 + 273.15 = 304.15 \text{ K}$$

$$PV = nRT \longrightarrow P = \frac{nRT}{V}$$

$$= \frac{(0.00\mathbf{1136} \text{ mol})(0.08206 \text{ L} \cdot \text{atm/mol} \cdot \text{K})(\mathbf{304}.15 \text{ K})}{\mathbf{4.6} \text{ L}}$$

$$= 0.00\mathbf{61}64 \text{ atm} \times \frac{760 \text{ torr}}{1 \text{ atm}} = \mathbf{4.7 \text{ torr}}$$

Try This On Your Own

8.0 g of CH_4(g) is added to a rigid container at 0 °C and exerts a pressure of 650 torr. An amount of O_3(g) is added to the container, causing the pressure to increase to 2600 torr. What mass of O_3(g) was added?

Try These On Your Own

- A 10.0-L cylinder contains 55.0 g $CO_2(g)$ at a temperature of 325 °C. What is the pressure (in atm) within the cylinder?

- What mass of $NH_3(g)$ will exert the same pressure as 12 mg of $H_2S(g)$ in the same container under the same conditions?

- How many gas particles are in a bedroom measuring 3.65 m × 3.05 m × 2.40 m at room temperature (25 °C) and standard atmospheric pressure (1.0 atm)?