Week 1 covers sections 1-5 of chapter 13 in the textbook. Topics include

- temperature and measurement scales
- measurements of amount and density
- the ideal gas law
- kinetic theory of gas

1. The Celsius temperature scale is based on the *triple point* of water, but it is more common to think of it as being 0 °C when water freezes and 100 °C when water boils at 1 atm of pressure. But the Fahrenheit scale is more well known to us so lets do some conversion of common Fahrenheit temperatures. 105 °F, 98.6 °F, 72 °F, 32 °F, 0 °F. Keep going down in Fahrenheit, and see if you can find a Fahrenheit temperature that gives you the same number in Celsius. Make sure you can go backwards and convert some Celsius temperatures back to Fahrenheit.

$T_F = \frac{9}{5} \cdot T_C + 32$

$\frac{9}{5} T_C = T_F - 32$

$T_C = \frac{5}{9}(T_F - 32)$

T_F	T_C
105°F	40.6°C
98.6°F	37°C
72°F	22°C
32	0
0	-18

$T = \frac{9}{5} \cdot T + 32$

$-\frac{4}{5} T = 32$

$T = -\left(\frac{5}{4}\right) \cdot 32$

$\boxed{T = -40}$

2. If I only tell you a *change* in Fahrenheit temperature of a substance but not the actual temperature, then you can figure out the corresponding change in Celsius, but still not the actual temp. A change in temperature measured in Fahrenheit is 1.8 times bigger than the change measured in Celsius. So if the temperature increased by 30 °F, then by how much does the temperature change in Celsius? What does this mean about the "size" of a Celsius degree vs. the "size" of a Fahrenheit degree? Which one represents a larger change in temperature?

$$\Delta T_F = \frac{9}{5} \Delta T_C$$

3. The kelvin temperature scale is designed as an *absolute* temperature scale, meaning the lowest temperature any object could theoretically be is set to 0 K. The size of a Kelvin degree is the same as the size of a Celsius degree, so that a 20 °C change in temperature is the same as a 20 K temperature change. Absolute zero in the Kelvin Scale is set to −273.15 °C. So, what is 0 °C in Kelvin? What is 20 °C in Kelvin. What is 70 K in Celsius? What is normal human body temperature in K?

$T_K = T_C + 273.15$

$T_C = T_K - 273.15$

T_C	T_K
−273.15°C	0 K
0°C	273.15K
20°C	293.15K
−203.15°C	70K
37°C	310K

$\Delta T_C = \Delta T_K$

4. What is absolute zero in the Fahrenheit temperature scale? Find this by using $T_C = -273.15$ first if you want, but then try using a substitution for T_C that will give you an expression for finding any Fahrenheit temperature given a Kelvin one.

5. What is the ~~molecular~~ ~~weight~~ (atomic mass) of Carbon-12? ($12 \frac{g}{mol}$) Find a periodic table to help. How many protons are in Carbon-12? How many neutrons? What about the number of protons in Carbon-14? What about the number of neutrons in Carbon-14?

6p 6p 6n 8n

atomic mass − # of protons = # of neutrons

6. How many atoms are in a mole of Helium? How many atoms are in a mole of Carbon-12? What is the mass of a mole of Helium? What is the mass of a mole of Carbon-12?

$m_{He} = 4g$

1 mole of He = $6.022 \cdot 10^{23}$ atoms → 12g

7. What is the mass of a single CO_2 molecule? What is the mass of a mole of CO_2?

$12g + 2(16) = 44g$

$\frac{44\,g}{6.022 \cdot 10^{23}\ \text{molecules}} = 7.3 \cdot 10^{23}\ \frac{g}{\text{molecule}} = 7.3 \cdot 10^{-26}\ kg$

8. What is the mass of a mole of dry air which is 78% N_2, 21% O_2, and 1% Ar?

↳ $28g \cdot 0.78 =$ ____

$32g \cdot 0.21 =$ ____

$40g \cdot 0.01 =$ ____

$29\ g/mol$

9. A balloon is filled with 0.4 mol of helium so that its volume is 0.010 m^3.

- Find the number of atoms.

$N = n \cdot N_A$

# of particles ↳ number of moles

$N = 0.4\ mol \cdot 6.022 \cdot 10^{23}\ \frac{\text{particles}}{mol} = 2.4 \cdot 10^{23}$ He atoms

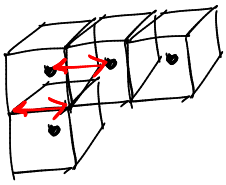
- Find the number density.

$\text{number density} = \frac{N}{V} = \frac{2.4 \cdot 10^{23}\ \text{atoms}}{0.010\ m^3} = 2.4 \cdot 10^{25}\ \text{He atoms}/m^3$

- Find the mass density. $4\ \frac{g}{mol} \cdot 0.4\ mol = 1.6\ g = 0.0016\ kg$

volumetric mass density = ρ ("rho") $= \frac{M}{V} = \frac{0.0016\ kg}{0.010\ m^3} = 0.16\ kg/m^3$

- Estimate the average distance between atoms. To do this, ~~find~~ find the *volume per particle*, and then treat that volume like a cube and find the side length of the cube. Draw a picture of this model and use that to justify your approximation.



number density = $\frac{\text{particle}}{\text{volume}}$ $\rightarrow$ $\frac{\text{volume}}{\text{particle}} = \frac{1}{2.4\cdot10^{25}\ \text{He atoms}/m^3} = 4.17\cdot10^{-26}\ \frac{m^3}{\text{atom}}$

$V_{cube} = s^3$

$s = \sqrt[3]{V} = \sqrt[3]{4.17\cdot10^{-26}\ \frac{m^3}{\text{atom}}} = 3.5\cdot10^{-9}\ m$

$= 3.5\ nm$

$= 35\ \text{Å}$

10. You have a pound of feathers and a pound of lead.
    - Which one weighs more? same
    - Which one has more mass? same
    - Which one has the greater volume? feathers
    - Which one contains a larger number of moles? brick
    - Which one contains a larger number of atoms? feathers
    - Which one contains a larger number of protons and neutrons? same

11. You check your car tire pressure and see that the pressure is 25 lb/in^2. What is this in Pascal? (You'll need to look up a conversion factor). This is a gauge pressure, so what is the absolute pressure in the tire?

$25\ psi \cdot \frac{1\ atm}{14.7\ psi} \cdot \frac{1.013\cdot10^5\ Pa}{1\ atm} = 1.7\cdot10^5\ Pa$ ← gauge pressure

$P_{abs} = P_{gauge} + P_{atm}$

$= 1.7\cdot10^5\ Pa + 1.013\cdot10^5\ Pa$

$P_{abs} = 2.7\cdot10^5\ Pa$

12. You check you car tire pressure when it is 15 °C and it is 25 lb/in^2. By what factor do you increase the number of particles in the tire so that the pressure becomes that 30 lb/in^2? (*Hint: The volume and temperature do not change.*)

13. The gas pressure inside of a 1 liter sealed container at room temperature is 1 atm. How many molecules are inside? How many moles of molecules?

$1\,L \cdot \frac{1000\,mL}{1\,L} \cdot \frac{1\,cm^3}{1\,mL} \cdot \frac{(1\,m)^3}{(100\,cm)^3} = 10^{-3}\,m^3$ (10^3, 10^6)

$= 0.001\,m^3$

$1\,atm = 1.013 \cdot 10^5\,Pa$

$PV = Nk_BT$

$N = \frac{PV}{k_BT} = \frac{10^5\,Pa \cdot 10^{-3}\,m^3}{1.38 \cdot 10^{-23} \cdot 293K} = 2.5 \cdot 10^{22}$ particles $= 0.041$ mol

Ideal Gas Law

microscopic: $PV = Nk_BT$ — P (Pa), V (m^3), N # of particles, k_B Boltzmann's $1.38 \cdot 10^{-23}\,J/K$

macroscopic: $PV = nRT$ — P atm (Pa), V Liters (m^3), n moles, T Kelvin

$0.08206\,\frac{atm\,L}{mol\,K}$ $\left(8.314\,\frac{J}{K \cdot mol}\right)$

14. If the pressure inside a tank is 1 atm when the temperature is 100 K, then what is the pressure when the temperature rises to 200 K?

15. If the pressure inside a tank is 1 atm when the temperature is 100 °C, then what is the pressure when the temperature rises to 200 °C? *CAREFUL!*

16. A gas is in a sealed container. By what factor does the pressure change if
    - the volume is doubled?
    - the temperature is tripled?
    - the volume is double and the temperature is tripled?
    - the volume is halved?

17. You are standing in a room at atmospheric pressure and room temperature. You estimate the room to be 10 m wide by 15 m long by 2 m high. How many moles of gas are in the room?