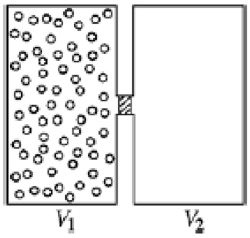
ENV-413: Thermodynamics of the Earth systems

Worksheet 1: Introduction, Composition

1. Consider a system where gas is confined to a subvolume V_1 in an insulated rigid container. The container has an adjoining subvolume V_2, initially evacuated, connected to V_1 by opening a valve ($V_1 = V_2$). When the valve is opened, gas fills the entire volume, $V_1 + V_2$.



If the amount of heat exchanged with the environment is negligible during the expansion, what type of process is the expansion?
Adiabatic Expansion

Is the first chamber (subvolume V_1) a closed system?
Once the valve is opened the system is no longer closed

If V_1 is not a closed system, then what system is?
Open

2. Identify each of the following variables as either extensive or intensive

Variable	intensive	extensive
Temperature	X	
Pressure	X	
Volume		X
Density	X	
Specific volume	X	
# of moles		X
salinity	X	

3. Units (check your equations to make sure that the units on both sides of the equal sign match!). The ideal gas law assumes that the gas molecules are infinitely small and that there are no intermolecular interactions. Real gases, particularly under conditions of high pressure, do not satisfy these conditions. Numerous different forms of the equation of state for real gases have been formulated. The *van der Waals equation of state* is a semi-empirical relation and is written as

$$\left(p+\frac{an^2}{V}\right)\left(V-nb\right)=nR^*T$$

where p is pressure, V is volume, T is temperature, and R^* is the universal gas constant. Find the dimensions of the constants a and b and express these dimensions in SI units.

Units

p - N/m^2 or Pa

V - m^3

T - K

n - mol

R^* - J/mol/K

J - Nm

To add or subtract the units must be the same so

$$\mathrm{N/m^2} = \frac{\mathrm{a\,mol^2}}{\mathrm{m^3}} \;\therefore\; \mathrm{a} = \frac{\mathrm{Nm}}{\mathrm{mol^2}} \text{ or } \frac{\mathrm{J}}{\mathrm{mol^2}}$$

$$\mathrm{m^3} = \mathrm{mol\,b} \;\therefore\; \mathrm{b} = \frac{\mathrm{m^3}}{\mathrm{mol}}$$

4. Molecular weight and mole fractions:

Element	Molecular weight (g mole^{-1})
Hydrogen	1
Oxygen	16
Sodium	23
Chlorine	35

a) Calculate the molecular weight of H_2O

1*2 + 16 = 18 g/mol

b) Calculate the molecular weight of NaCl

23 + 35 = 58 g/mol

c) A water solution has salt concentration of 3.5% by mass. What is the mole fraction of this solution, where the mole fraction is the ratio of the number of moles of salt to the total number of moles (water + salt)?

$$\frac{mol\;NaCl}{mol\;NaCl+mol\;H_2O} = \frac{\frac{3.5}{58}}{\frac{3.5}{58}+\frac{96.5}{18}} = 1.113\%$$

5. Which two gases are most abundant in the atmosphere?

Nitrogen and Oxygen

6. Which atmospheric gas(es) can condense under normal atmospheric conditions?

Water Vapor (H_2O)

7. What is a typical salinity of the ocean?

34.7psu (practical salinity units)

8. List at least 3 processes that modify the surface salinity of the ocean:

Evaporation Precipitation River Runoff Glacier Melt

9. Using the data listed in Table 1.2, consider the following questions:

a) In seawater, the proportion by weight of negative ions greatly exceeds that of positive ions. Why does seawater not carry a net negative charge?
Even though the table suggests that by 'weight' negative ions greatly exceed positive ions, if you consider it by mol, you achieve a different balance.

b) What is the ratio of potassium concentration to total salinity? What would the potassium concentration be if the salinity rose to 36 psu? If it fell to 33 psu?

$\frac{0.380\ K}{34.482\ Total}$ or 1.1% $\frac{0.380\ K}{36\ Total}$ or 1.06% $\frac{0.380\ K}{33\ Total}$ or 1.15%

10. Match the atmospheric particle to a representative size (note you can you use the same size more than once) (NOTE: info not in chapter 1, use logic!)

____e_____	Raindrop	a.	0.1 μm
____d_____	Ice crystal	b.	1 μm
____a_____	Aerosol particle	c.	10 μm
____c_____	Cloud drop	d.	100 μm
____f_____	Snow flake	e.	1 mm
		f.	1 cm
		g.	1 m