IH Chemistry and Math Review

Lecture 1

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Equations

$\text{Mass} = \rho * \text{Vol}$ $SpGr = \frac{\rho_{liquid}}{\rho_{water}}$ $T_R = 460\ °R + T_F$ $T_K = 273\ °C + T_C$

$PV = nRT$ $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ $NoMoles = \frac{Vol_{cont}}{AvVol}$ $NoMoles = \frac{Mass}{MW}$

$$AvVol = 24.45\,L\ x\ \frac{273.16 + T_C}{273.16 + 25C}\ x\ \frac{760mmHg}{P_{bar}}$$

$Vol_{cont} = \left(\frac{Conc_{ppm}}{10^6\ ppm}\right) Vol_{air}$ $Volume = NoMoles\ x\ AvVol$

$Conc_{mg/m^3} = \frac{MW}{AvVol}\ x\ Conc_{ppm}$ $Conc_{ppm} = \frac{AvVol}{MW}\ x\ Conc_{mg/m^3}$ $Conc_{ppm} = \frac{Vol_{cont}}{Vol_{air}}\ x\ 10^6\ ppm$

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Reference Temperatures and Pressures

STP - Standard Temperature and Pressure
Commonly used for chemical and physical processes.
0°C (273.15 K, 32F) and 1 atm (101.325 kN/m2,
101.325 kPa, 14.7 psia, 0 psig, 29.92 in Hg, 760 torr,
33.95 Ft.H2O, 407.2 In.W.G, 2116.8 Lbs./Sq.Ft.)

NTP - Normal Temperature and Pressure (OSHA/NIOSH/ACGIH)
25 °C (298.15 K) and 760 mm Hg (101.325 kPa), molar vol = 24.46 L

NTP - Normal Temperature and Pressure (European and U.S. Ventilation)
20 C (293.15 K, 68 F) and 1 atm (101.325 kN/m2,
101.325 kPa, 14.7 psia, 0 psig, 29.92 in Hg, 760 torr.
Density 1.204 kg/m3 (0.075 pounds per cubic foot)

SATP - Standard Ambient Temperature and Pressure
Also used in chemistry as a reference with temperature of 25 degC
(298.15 K) and pressure of 101 kPa.

ISA - International Standard Atmosphere
Reference for aircraft performance
101.325 kPa, 15 C and 0% humidity.

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Adjusting TLVs to non-NTP conditions

- *Application of TLVs® to Unusual Ambient Conditions.* When workers are exposed to air contaminants at temperatures and pressures substantially different than those at normal temperature and pressure (NTP) conditions (25°C and 760 torr), care should be taken in comparing sampling results to the applicable TLVs®. For aerosols, the TWA exposure concentration (calculated using sample volumes not adjusted to NTP conditions) should be compared directly to the applicable TLVs® published in the *TLVs® and BEIs®* book. For gases and vapors, there are a number of options for comparing air-sampling results to the TLV®, and these are discussed in detail by Stephenson and Lillquist (2001). One method that is simple in its conceptual approach is 1) to determine the exposure concentration, expressed in terms of mass per volume, at the sampling site using the sample volume **not** adjusted to NTP conditions, 2) if required, to convert the TLV® to mg/m3 (or other mass per volume measure) using a molar volume of 24.4® L/mole, and 3) to compare the exposure concentration to the TLV®, both in units of mass per volume.

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Avogadro's Volume: molar volume of any gas

At 0C, 760 mmHg, AvVol =	22.414 L
At 20C, 760 mmHg , AvVol =	24.055 L
At 25C, 760 mmHg , AvVol =	24.465 L
At 70F, 760 mmHg , AvVol =	24.146 L

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Density

- Density (ρ) is the amount of matter contained in a unit volume of a substance
- ρ = Mass/Volume
- Reference density: water
  - English - 8.345 lb/gal
  - Metric - 1 g/mL_{liq}

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Specific gravity

The ratio of the weight or mass of a given substance, at a specified temperature, to that of an equal volume of another reference substance

- Reference of liquid or solid is water
- Reference of gases is air or H_2

$$SpGr = \frac{\rho_{liquid}}{\rho_{water}}$$

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Problem 1

- Find the specific gravity of acetone if the density is 6.54 lb/gal.

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Problem 1 solution

$$SpGr = \frac{\rho_{liquid}}{\rho_{water}} = \frac{6.54\,lb/gal}{8.33\,lb/gal} = 0.79$$

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Problem 2

- Find the density in lb/gal of carbon disulfide if the SpGr is 1.26.

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Problem 2 solution

$$SpGr = \frac{\rho_{liquid}}{\rho_{water}}$$

- Find the density in lb/gal of carbon disulfide if the SpGr is 1.26.

$$\rho_{CS_2} = SpGr_{CS_2} \times \rho_{H_2O}$$
$$= 1.26 \times 8.33 \text{ lb/gal}$$
$$= 10.5 \text{ lb/gal}$$

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Problem 3

- Given the specific gravity of carbon disulfide is 1.26, what is the mass of 75 ml of CS_2?

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Problem 3 solution

- Given the specific gravity of carbon disulfide is 1.26, what is the mass of 75 ml of CS_2?

$$\text{Mass of } CS_2 = \rho * \text{Vol}_{liq}$$

$$= \text{SpGr}_{CS_2} \, x \rho_{H_2O} * \text{Vol}_{liq}$$

$$\text{Mass of } CS_2 = 1.26 \times 1.00 \ \frac{g}{ml} \times 75\,ml$$

$$= 94.5g$$

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Problem 4

- If 94.5 g of CS_2 were vaporized, how much vapor would be produced?

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Problem 4 solution

$$Volume = NoMoles\ \ x\, Vol / mole$$

$$Mass = NoMoles\ x\ MassPerMole$$

- If 94.5 g of CS_2 were vaporized, how much vapor would be produced @25C and sea level?
- Solution: Determine number of moles

  Based on the molar volume determine the total volume

$$AvVol = 24.45\ x\ \frac{273.16 + T_C}{273.16 + 25C}\ x\ \frac{760mmHg}{P_{bar}} = 24.45 L / mole$$

$$NoMoles\ = \frac{Mass}{MW}\ = \frac{94.5g}{(12 + 2x32)g / mole} = \frac{94.5\,moles}{76} = 1.243\,moles$$

$$Volume = NoMoles\ x\ AvVol\ = 1.234\,moles\ x\ 24.45 L / mole$$

= 30.4 L

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Problem 5

- If that volume of vapor were to be diluted with 10 m^3 of clean air, what would the concentration be in PPM?

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Problem 5 solution

If that volume of vapor were to be diluted with 10 m^3 of clean air, what would the concentration be in PPM?

$$Conc_{ppm} = \frac{Vol_{cont}}{Vol_{air}} x\,10^6\ ppm$$

$$= \frac{30.3L}{30.3L + 10m^3 x 1000 \frac{L}{m^3}} x\,10^6\ ppm = 3030 \text{ ppm}$$

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Problem 6

- What is the mass, in mg, of CS_2 in a 10 Liter sample of air collected at 25° C, if the concentration of CS_2 in the sample is 500 PPM?

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Problem 6 solution

What is the mass, in mg, of CS_2 in a 10 Liter sample of air collected at 25° C, if the concentration of CS_2 in the sample is 500 PPM?

1) Calculate the volume of pure CS_2 needed to produce 500 PPM in 10 L.
2) Determine number of moles in that volume.
3) Determine mass from the number of moles and the gram molar (GMW) weight.

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$$Conc_{ppm} = \frac{Vol_{cont}}{Vol_{air}} x\,10^6\ ppm$$

Problem 6 solution - continued

What is the mass in mg of CS_2 in a 10 Liter sample of air collected at 25° C, if the concentration of CS_2 in the sample is 500 PPM?

1) Calculate the volume of pure CS_2 needed to produce 500 PPM in 10 L.

$$Vol_{cont} = \left(\frac{Conc_{ppm}}{10^6\ ppm}\right) Vol_{air} = \left(\frac{500\ ppm}{10^6\ ppm}\right) 10L \quad = 5x10^{-3}\ \mathrm{L}$$

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Problem 6 solution - continued

What is the mass in mg of CS_2 in a 10 Liter sample of air collected at 25° C, if the concentration of CS_2 in the sample is 500 PPM?

1) Calculate the volume of pure CS_2 needed to produce 500 PPM in 10 L. Vol = $5x10^{-3}$ L

2) Determine number of moles in that volume.

$$NoMoles = \frac{Vol_{cont}}{Vol_{one\ mole}} = \frac{5x10^{-3} L}{24.4 L / mole} = 2.05x10^{-4}$$

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Problem 6 solution - continued

What is the mass in mg of CS_2 in a 10 Liter sample of air collected at 25° C, if the concentration of CS_2 in the sample is 500 PPM?

2) Number of moles in that volume =$2.05x10^{-4}$ moles

3) Determine mass from the number of moles and the MW.

MW_{CS_2} = 12+2x32 = 76g/mole=78000 mg/mole

$$Mass = NoMoles\ x\ WtPerMole$$
$$= NoMoles\ x\ MW / mole$$
$$= 2.05\,x10^{-4} moles\ x\ 76000 mg / mole = 15.6\, mg$$

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$$AvVol = 24.45\,L \ x \ \frac{273.16 + T_C}{273.16 + 25C} \ x \ \frac{760\,mmHg}{P_{bar}}$$

Equations to convert from ppm to mg/m³

$$Conc_{ppm} = \frac{AvVol}{MW} \ x \ Conc_{mg/m^3}$$

$$Conc_{mg/m^3} = \frac{MW}{AvVol} \ x \ Conc_{ppm}$$

When converting values expressed as an element (e.g., as Fe, as Ni), the molecular weight of the element should be used, not that of the entire compound.

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Absolute Temperature

- Degree Rankin (°R)- English

  T_R = 460 °R + T_F

- Degree Kelvin (°K) – metric

  T_K = 273 °C + T_C

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General Gas Law

$$PV = nRT$$

$$PV = nRT$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

- Permits the determination of the value of any of the three basis characteristics of the gas/vapor being evaluated that result from changes to one or both of the other two characteristics.

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STP volume correction for NTP

$$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}$$

$$V_2 = \frac{T_2}{P_2} \times \frac{P_1 \times V_1}{T_1}$$

$$V_2 = V_1 \times \left(\frac{T_2}{T_1}\right) \times \left(\frac{P_1}{P_2}\right)$$

$$V_2 = 22.25\,L \times \left(\frac{298°K}{273°K}\right) \times \left(\frac{760\,mmHg}{760\,mmHg}\right)$$

$$V_2 = 24.5\,L \text{ at } 25\,°C \text{ and } 760\,mmHg$$

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The End

The End

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