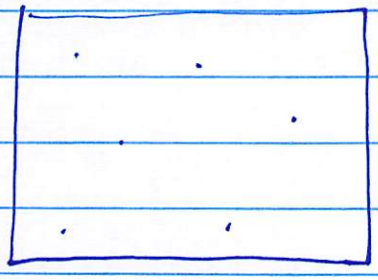
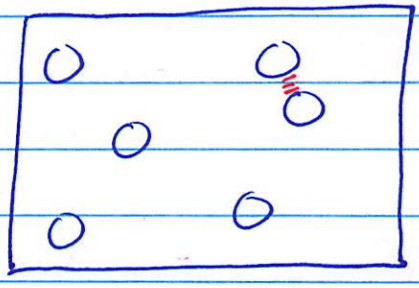
10/29/2018

Real gases

ideal gas



real gases



molecules have no V

molecules have volume themselves!

molecules have no attraction for one another

molecules <u>are</u> attracted to each other.

IDEAL: $P \cdot V = nRT$

REAL: $(P + \text{correction for attractions})(V + \text{correction for molecular volume}) = nRT$

van der Waals equation

1873: 2 correction factors: a, b

a: related to attraction between molecules

b: related to size of molecules.

vdW eq: $\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$

Van der Waals's Equation

- Combining the equations to account for molecular volume and intermolecular attractions we get the following equation.
  - Used for real gases

$$\left[P + a\left(\frac{n}{V}\right)^2\right] \times [V - nb] = nRT$$

Correction for intermolecular forces

Correction for particle volume

TABLE 5.5 Van der Waals Constants for Common Gases

Gas	a ($L^2 \cdot atm/mol^2$)	b (L/mol)
He	0.0342	0.02370
Ne	0.211	0.0171
Ar	1.35	0.0322
Kr	2.32	0.0398
Xe	4.19	0.0511
H_2	0.244	0.0266
N_2	1.39	0.0391
O_2	1.36	0.0318
Cl_2	6.49	0.0562
H_2O	5.46	0.0305
CH_4	2.25	0.0428
CO_2	3.59	0.0427
CCl_4	20.4	0.1383

ex: $Xe(g)$ $\quad a = 4.19 \frac{L^2 \cdot atm}{mol^2}$; $b = 0.0511 \frac{L}{mol}$

let's calculate P_{Xe} for:

$+273.15 \rightarrow 310.15\,K$

$2.00\,mol\ Xe(g)$, $37^\circ C$, $2.00\,L$

assume: (1) ideal gas , (2) vdW gas

1) $pV = nRT$, $p = \frac{nRT}{V} = \frac{2.00\,mol \times 0.08206 \frac{atm \cdot L}{mol \cdot K} \times 310.15\,K}{2.00\,L}$

$= 25.45\ atm$ ideal

13% high

2) $\left(p + \frac{an^2}{V^2}\right)(V - nb) = nRT$ $\quad \Rightarrow p + \frac{an^2}{V^2} = \frac{nRT}{V-nb}$

$V - nb$ $\qquad V - nb$ $\qquad -\frac{an^2}{V^2}$ $\qquad -\frac{an^2}{V^2}$

$\Rightarrow p = \frac{nRT}{V-nb} - \frac{an^2}{V^2}$

$p = \frac{2.00\,mol \times 0.08206 \frac{atm \cdot L}{mol \cdot K} \times 310.15\,K}{2.00\,L - 2.00\,mol \times 0.0511 \frac{L}{mol}} \ominus \frac{4.19 \frac{L^2 \cdot atm}{mol^2} \times (2.00\,mol)^2}{(2.00\,L)^2}$

$= 26.821\ atm \ominus 4.19\ atm = 22.63\ atm$ vdW

0.4% low

NIST Reality (xpt) $P_{Xe} = 22.53\,atm$

Comment: for most gases around: 0-2 atm and 300K } ideal (✓)

severe deviations: 1) high p (molecules are close together)

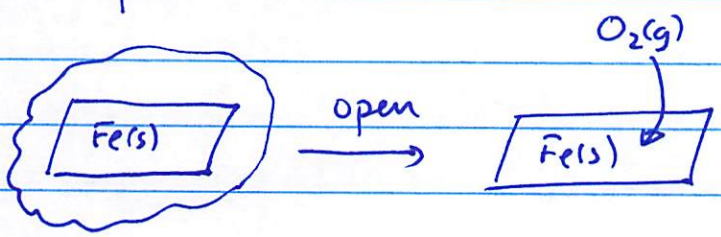
2) low T (... low speeds ... gas molecules stick!)

Ch 6: Thermochemistry

So far... we've only considered matter. What about energy?

Cold : hot pack!

Weather



rxn: $4Fe(s) + 3O_2(g) \longrightarrow 2Fe_2O_3(s) + \text{heat}$

Redox

FRH: $\overset{(0)}{Mg}(s) + 2H_2O(l) \longrightarrow \overset{(+2)}{Mg(OH)_2} + \overset{(0)}{H_2} + \text{heat}$

(flameless ration heater: ↑ 100°F temp increase, 10 mins to 50 kJ heat

Nature of energy

Energy = capability to do work
└ action of a force over a distance.

heat = energy flow due to a temp difference.

Types of energy → KINETIC ENERGY (motion) → ex: Thermal Energy ("heat") associated w/ movement of atoms/e⁻s.

↓

POTENTIAL ENERGY (position) → ex: Chemical energy assoc. w/ position of atoms/e⁻s

Energy conservation + energy transfer.

law of conservation of E: "Energy can neither be created nor destroyed"

- just changed form/ interconverted