Mon: HW by 5pm
(Aug 27) Ex 324, 325, 326, 327, 328, 329, 330

Ch 12 Prob 14

Weds Warm Up 14 D2L

Thermal physics

Thermal physics (thermodynamics) considers physical systems that consist of very large numbers of individual constituents. There are too many to describe the state of each individual satisfactorily and we need to develop a description of the bulk properties of the system.

DEMO: PhET Gas Properties

* Tab → Ideal
* Inject 100 light, 1 heavy
* Observe – motion of heavy
  – bulk gas properties : pressure, volume, temp.

The common example that we will use to illustrate thermal physics is a dilute gas. We can describe the state of the gas by:

1) number of gas particles
2) volume of gas – same as container
3) pressure of the gas
4) temperature of the gas

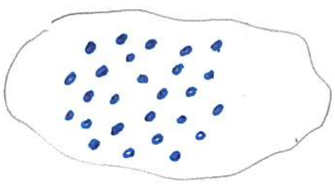
Number of gas particles

Typical gases that we encounter have a large number of particles (about 10^{25} per meter^3). Because this number is so large, we express the number of particles via a special number, Avogadro's number

$$N_A = 6.02 \times 10^{23}$$

We then describe the number of particles as a ratio.

Given a system containing N particles $\Rightarrow$ The number of moles (of particles) in the system is



$$n = \frac{N}{N_A}$$

Units: mol

Quiz 1 50% – 60%

The number of moles in a system can be determined for a pure chemical substance via:

Known formula for substance $\rightarrow$ Use periodic table to determine mass of one mole (in grams) $\rightarrow$ Number of moles $n = \frac{M}{M_{mola}}$ (M ← mass in grams; M_{mola} ← mass one mol in grams)

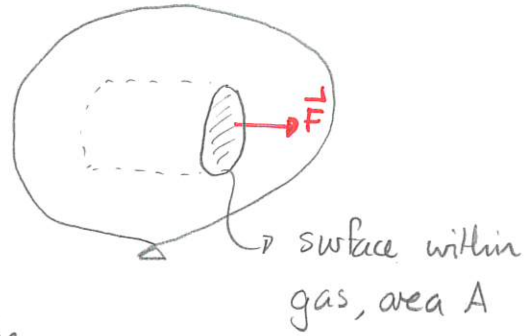
For example ethane is a gas with formula C_2H_6. Then

one mole
mass C $\rightarrow$ 12g
mass H $\rightarrow$ 1g
$\Rightarrow$ mass one mole $C_2H_6 = 2 \times 12g + 6 \times 1g = 30g$

Quiz 2 95%

Pressure and Temperature

Again, pressure describes the force per unit area that the gas exerts on any surface, via $P = F/A$.



In the gases that we consider the pressure will be the same throughout the gas. (unlike more dense fluids like water). So we can use one variable to describe the gas pressure everywhere.

The temperature of the gas can be measured using thermometry. The appropriate unit of temperature is Kelvin, K. We can determine the temperature in Kelvin via

$$T_K = T_C + 273\,°K$$

In Kelvin (T_K), In Celsius (T_C)

	Celsius	Kelvin
Freezes	0°C	273K
Boils	100°C	373K.

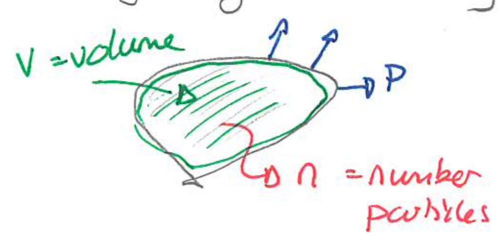
Thus we have special temperatures for water →

The gases that we will consider will be in equilibrium, which means that the temperature throughout the gas is the same everywhere

Ideal gases

In general we can describe the state of a gas by the following set of variables

1) number of moles of gas: n
2) volume of gas: V in m^3
3) pressure of gas: P in Pa
4) temperature of gas: T in K



These will not always be independent - so if we know three of the four variables, we can determine the remaining one

DEMO: PhET Gas Properties

- Keep temperature fixed
- Vary volume - observe pressure

For sufficiently dilute gases, basic statistical physics and thermodynamics as well as experimental evidence gives the ideal gas law:

$$\boxed{PV = nRT}$$

where $R = 8.314 \frac{J}{mol \cdot K}$ is the gas constant. This is the same for all gases

Quiz 3 20%

322 Helium balloon

A spherical balloon with radius 0.50 m contains helium at pressure 1.00 atm (1.01×10^5 Pa) at temperature 20.0° C. *(111F2023)*

a) Determine the number of moles of helium in the balloon.

b) The balloon rises to a point where the pressure is 0.480 atm and the temperature is −24.0° C. Determine the volume of the balloon at this altitude.

Answer: a) $PV = nRT$

$$\Rightarrow n = \frac{PV}{RT}$$

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi (0.50\,m)^3 = 0.52\,m^3$$

$$P = 1.01 \times 10^5\,Pa$$

$$T = 20 + 273 = 293\,K$$

$$\Rightarrow n = \frac{1.01\times10^5\,Pa \times 0.52\,m^3}{8.314\,\frac{J}{mol\cdot K} \times 293\,K}$$

$$= 21.7\,mol$$

b) The number of moles stays constant

$PV = nRT$

$$\Rightarrow \frac{PV}{T} = nR \text{ is constant}$$

$$\Rightarrow \frac{P_f V_f}{T_f} = \frac{P_i V_i}{T_i}$$

Initial	Final
$P_i = 1.01\times10^5\,Pa$	$P_f = 0.480 \times 1.01\times10^5\,Pa = 0.48\times10^5\,Pa$
$V_i = 0.52\,m^3$	$V_f = ??$
$T_i = 293\,K$	$T_f = -24 + 273 = 249\,K.$

$$\Rightarrow V_f = \frac{T_f}{P_f}\frac{P_i}{T_i}V_i \Rightarrow V_f = \frac{T_f}{T_i}\frac{P_i}{P_f}V_i$$

$$= \frac{249\,K}{293\,K}\,\frac{1.01\times10^5\,Pa}{0.48\times10^5\,Pa}\,V_i = 1.8\,V_i$$

$$\Rightarrow V_f = 1.8 \times 0.52\,m^3$$

$$V_f = 0.93\,m^3$$