
SUPERMAN

Properties of Gases

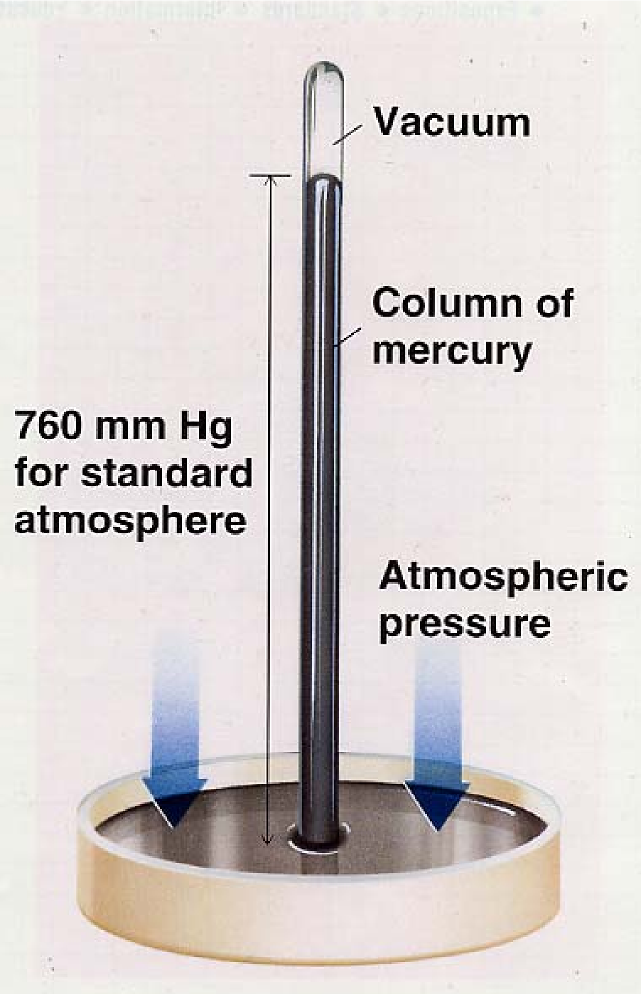
- PRESSURE: Units and Measurement
- Avogadro’s Law
- Charles’ Law
- Boyle’s Law
- Ideal Gas Law
- Dalton’s Law

PRESSURE
Units and Measurement

Pressure = Force/Area

- SI Units
  - Force = mass x acceleration
  - Force = kg-m/s^2 = Newton
  - Pressure = Newton/m^2 = Pascal
- Customary Units
  - Pressure = atmospheres, torr, mmHg
  - Relate SI to customary
  - 1.013 X 10^5 Pascal = 1 Atm = 760 torr

PRESSURE
Mercury Barometer



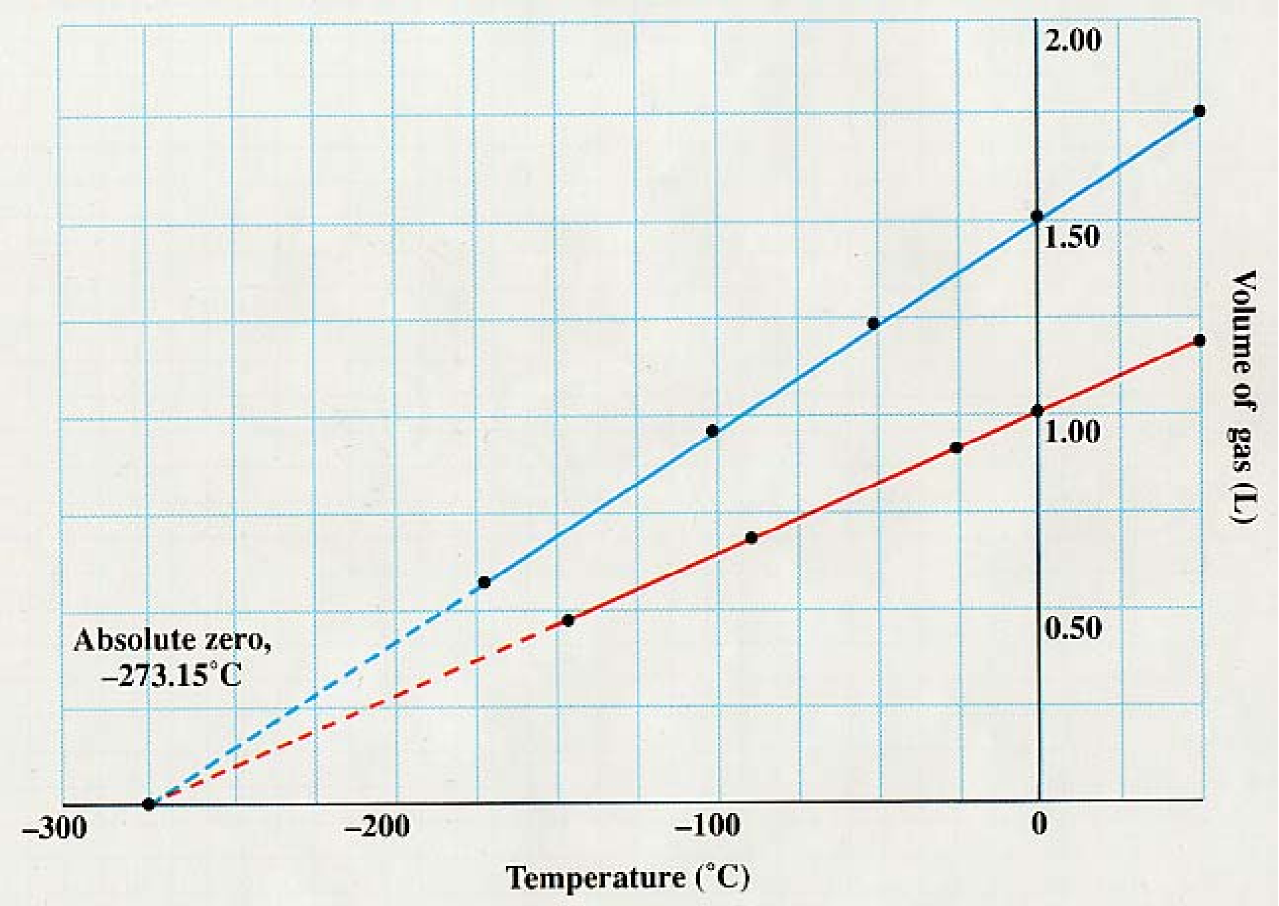
Avogadro's Hypothesis

Equal volumes of gases contain the same number of molecules at constant T,P

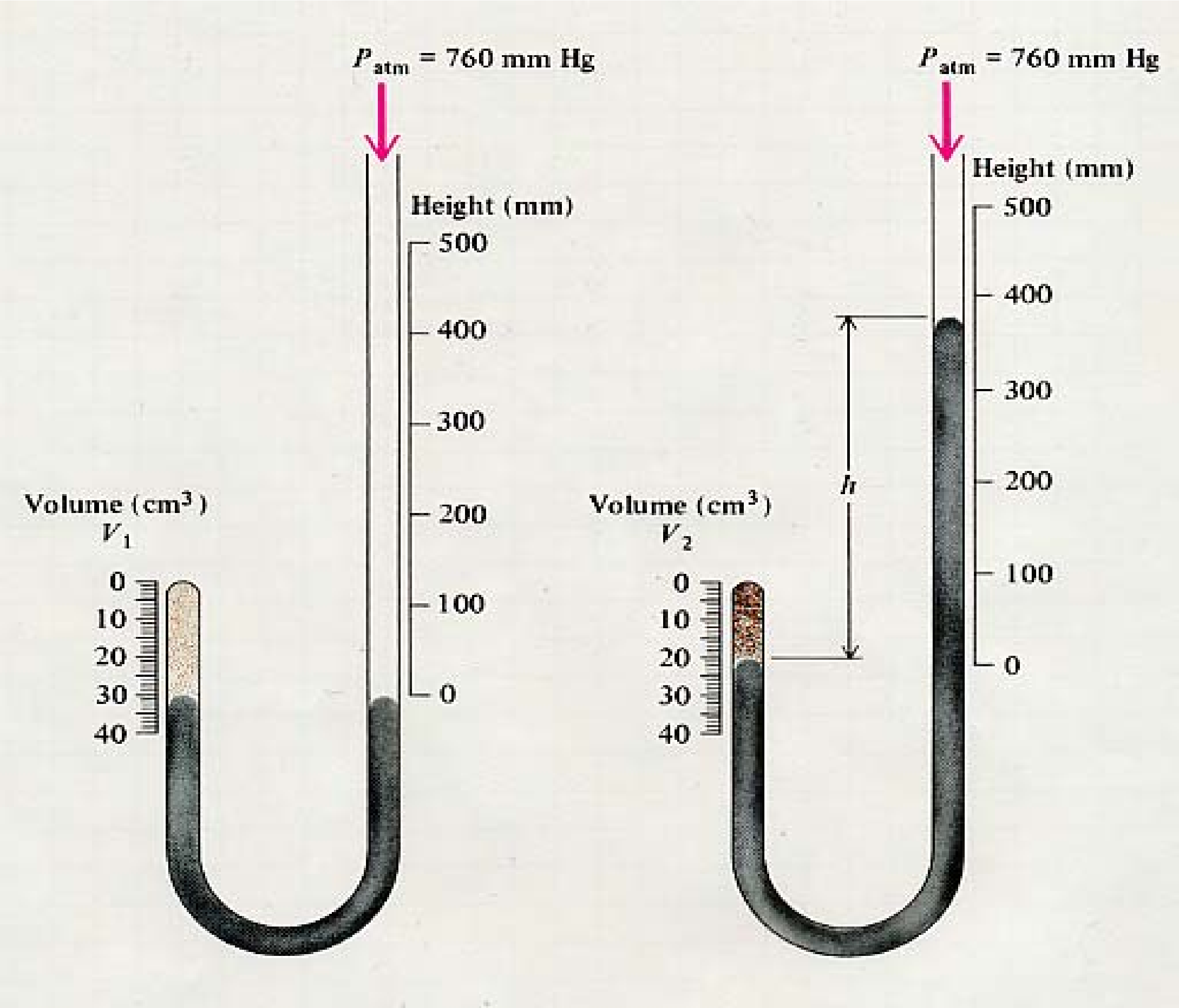
22.414 L of any gas contains 6.022×10^{23} atoms (or molecules) at STP

Charles' Law
Definition of Temperature

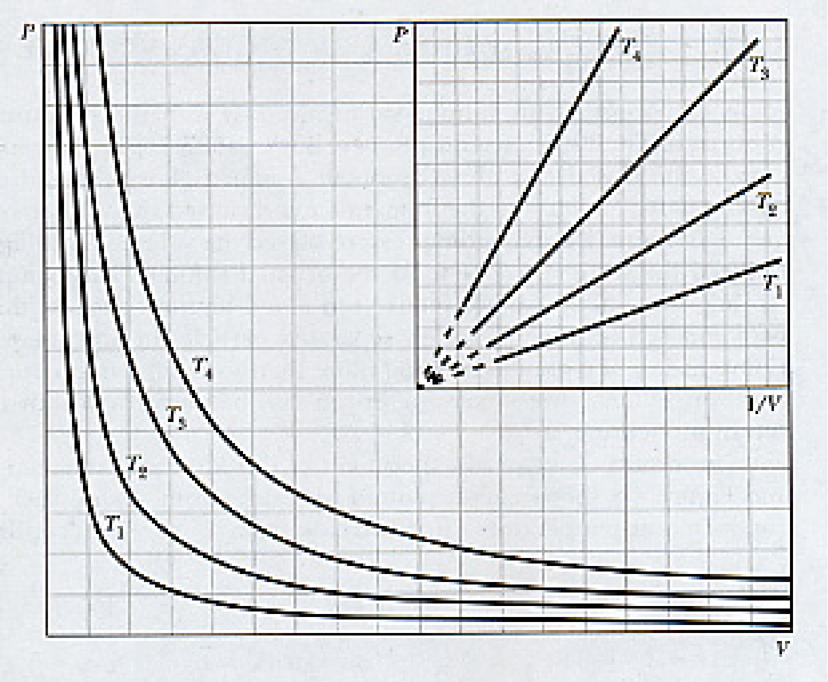
$V = V_0 - V_0\alpha t$



Boyle's Law



P_{atm} = 760 mm Hg
Height (mm)
500
400
300
200
100
0
Volume (cm³)
V_1
0
10
20
30
40
P_{atm} = 760 mm Hg
Height (mm)
500
400
300
200
100
0
h
Volume (cm³)
V_2
0
10
20
30
40


P
V
T1
T2
T3
T4
P
1/V
T4
T3
T2
T1

Ideal Gas Law
PV = nRT

- Charles: V vs T at constant n,P
- Boyle: P vs V at constant n,T
- Avogadro:effect of changing n
- Compressibility Factor: PV/RT = 1
- Molecular weight from density:

n= moles = g/M; d = density = g/V

$$PV = (g/M)RT$$

$$M = (g/V)(RT/P)$$

Dalton's Law
Partial Pressures

$$P_T = p_A + p_B + p_C$$

$$= X_A P_T + X_B P_T + X_C P_T$$

where $X_A + X_B + X_C = 1$

Air Bag Chemistry

Air Bag Chemistry

QuickTime™ and a YUV420 codec decompressor are needed to see this picture.

Automotive Airbags -

What Now?

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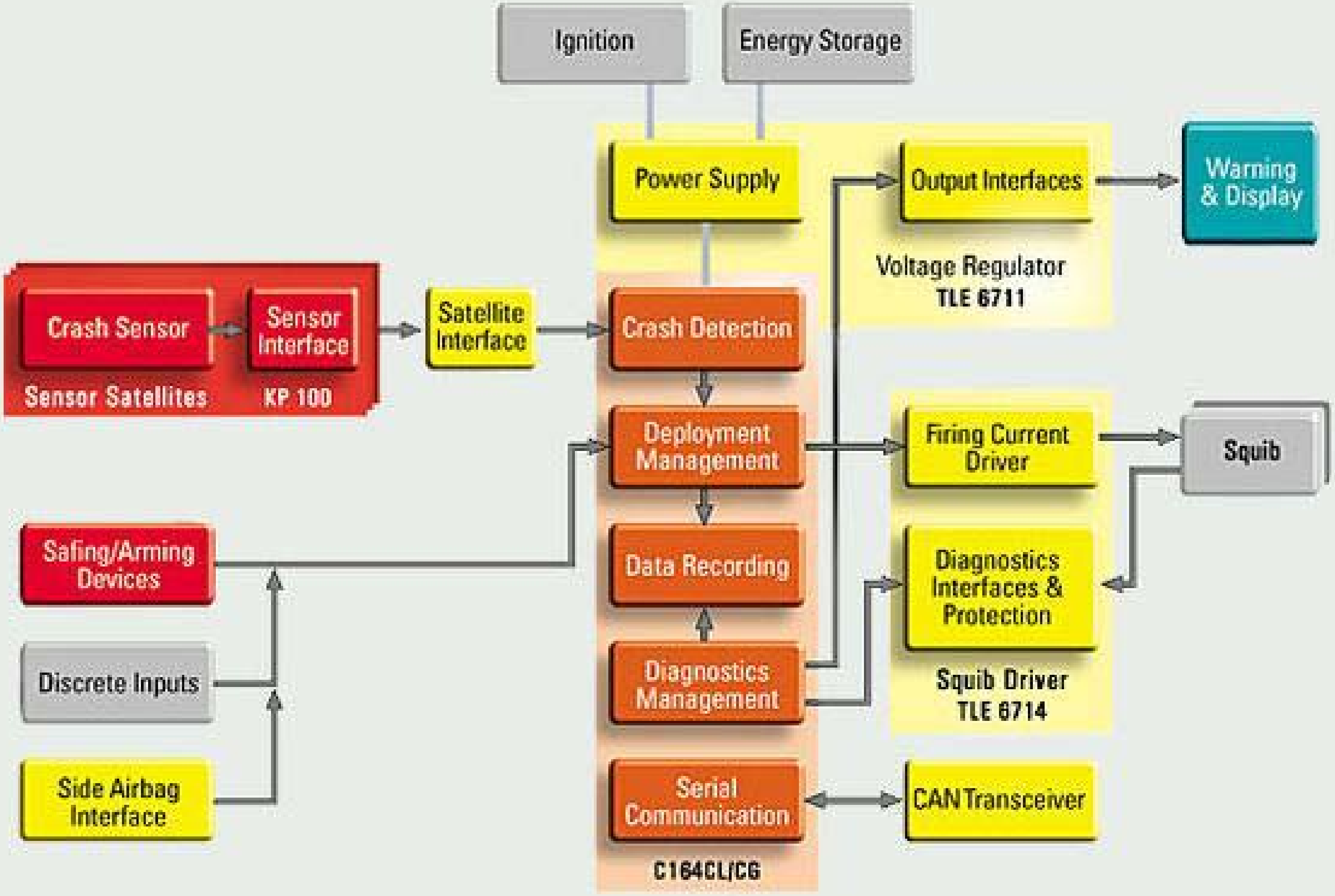
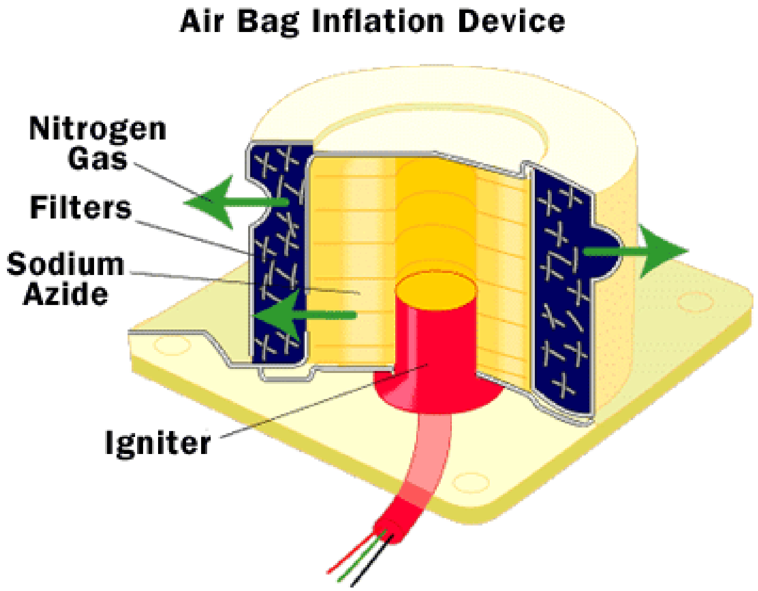
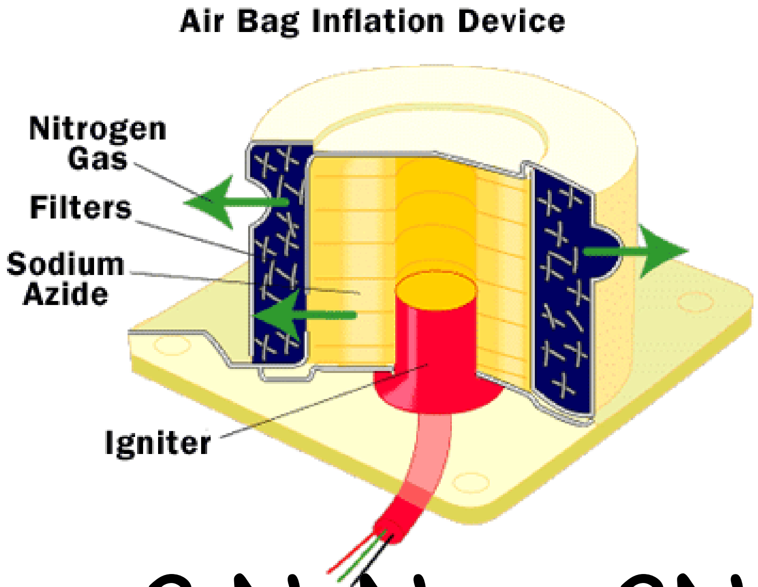

Ignition
Energy Storage
Power Supply
Output Interfaces
Warning & Display
Voltage Regulator
TLE 6711
Crash Sensor
Sensor Interface
Sensor Satellites
KP 100
Satellite Interface
Crash Detection
Deployment Management
Firing Current Driver
Squib
Safing/Arming Devices
Data Recording
Diagnostics Interfaces & Protection
Discrete Inputs
Diagnostics Management
Squib Driver
TLE 6714
Side Airbag Interface
Serial Communication
CAN Transceiver
C164CL/CG

Air Bag Chemistry



Air Bag Chemistry



Air Bag Inflation Device

On ignition: $2\ NaN_3 \Rightarrow 2Na + 3N_2$

Secondary reactions:

$10\ Na + 2\ KNO_3 \Rightarrow K_2O + 5\ Na_2O + N_2$

$K_2O + Na_2O + SiO_2 \Rightarrow K_2Na_2SiO_4$

Kinetic-Molecular Theory for Gaseous Behavior

Relates the easily observable P-V-T properties of gases to less easily recognizable properties such as numbers of particles and their speeds.

Kinetic-molecular theory is based on a simple theoretical model of a gas as a collection of colliding particles.

Kinetic-Molecular Theory for Gaseous Behavior

Key Assumptions and Features:

- Particles are widely separated and negligibly small
  d(N2,g) = 0.00125 g/L (273°C)
  d(N2,liq) = 0.808 g/mL (-195.8°C)
- No attractive or repulsive forces. Therefore, gases behave independently and expand spontaneously.
- Constant motion and elastic collisions account for diffusion and the time-independence of pressure.
- Mechanical work measured as $K.E.=(1/2)mv^2$
- Increasing T increases KE and increases P

Kinetic-Molecular Theory for Gaseous Behavior

- P_T is a function of two factors:
  - # of impacts/unit area/unit time
  - change in momentum (Δmv) on impact

Kinetic-Molecular Theory for Gaseous Behavior

- # of Impacts
  - Directly proportional to N, the number of molecules contained
  - Inversely proportional to V, the volume of the container
  - Directly proportional to v, the velocity of the molecules

NET RESULT: # of impacts α (N)(1/V)(v)

Kinetic-Molecular Theory for Gaseous Behavior

- Change in momentum Δmv
  - Directly proportional to m with heavier molecules causing a greater effect
  - Directly proportional to v with faster molecules causing a greater effect

NET RESULT: $\Delta mv \;\; \alpha \;\; (m)(v)$

Kinetic-Molecular Theory for Gaseous Behavior

of Impacts

NET RESULT: # of impacts α (N)(1/V)(v)

Change in momentum Δmv

NET RESULT: Δmv α (m)(v)

P_T α [#of impacts][Change in momentum]

P_T α [(N)(1/V)(v)][(m)(v)] = (N/V)(mv2)

P_T α (n/V)(T)

P_T = nRT/V

Kinetic-Molecular Theory for Gaseous Behavior

- Principal Issues (drawbacks)
  - Negligible Volume and No interaction
    - Hold only at low P, high T; for dilute gases
  - Elastic Collisions
    - Only in Neutonian mechanics is the reverse of an event as likely as the event itself.
    - In the real world you cannot "unscramble" eggs because of entropy effects resulting from large ensembles of molecules

Root Mean Square Speed

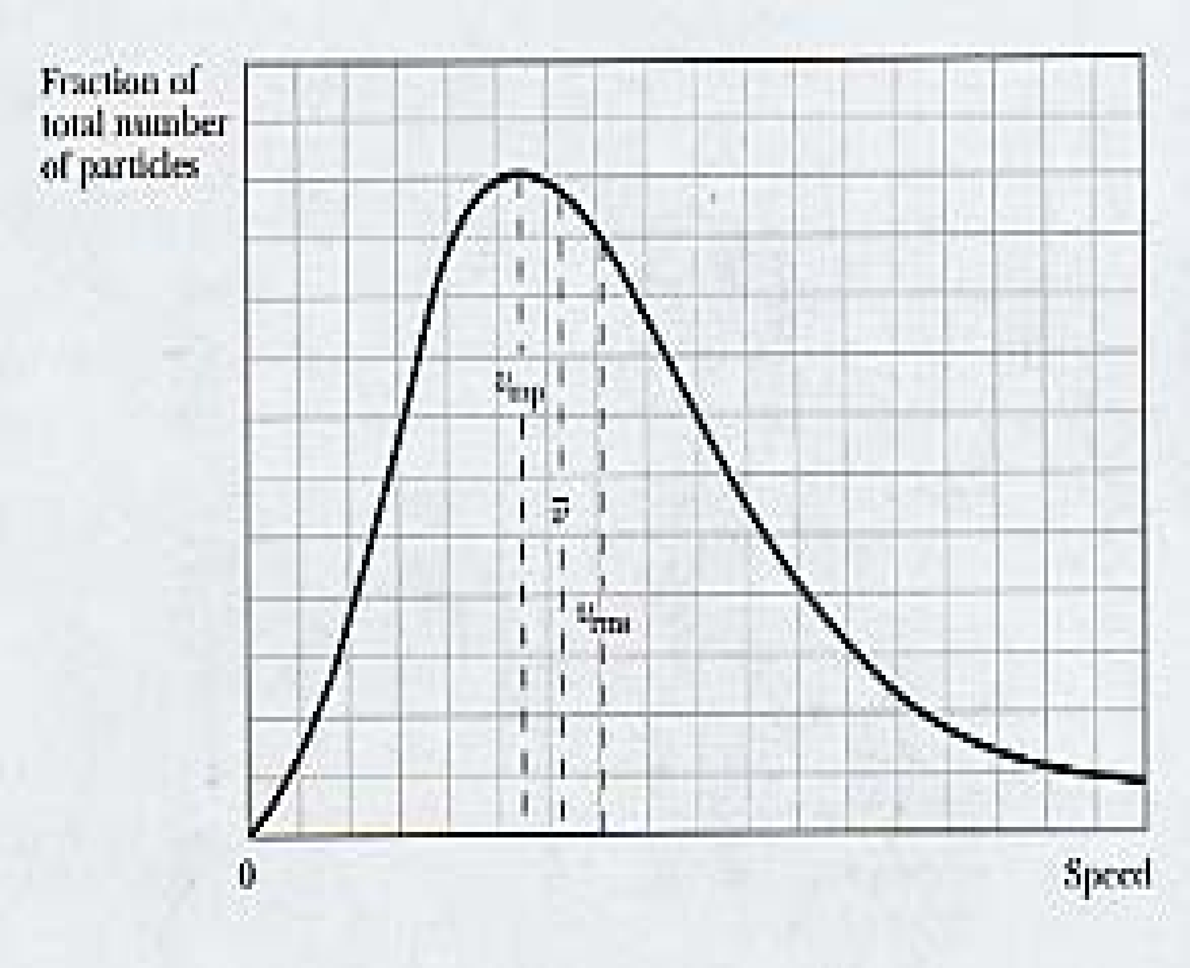
$\langle v \rangle_{rms}$

- Is the speed of an oxygen molecule....

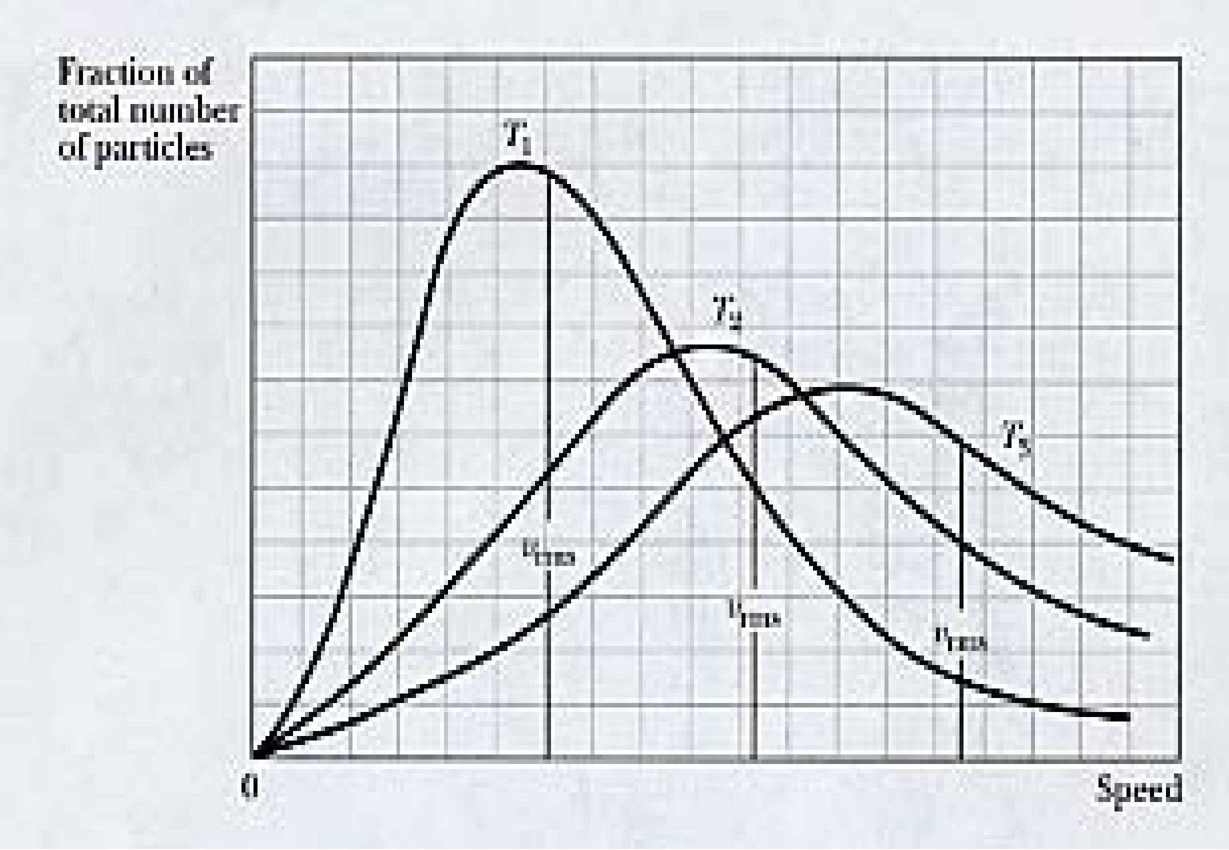
  faster than a speeding car?
  faster than a speeding plane?
  faster than a speeding bullet?

DO THE CALCULATION
FIND THE SURPRISING RESULT

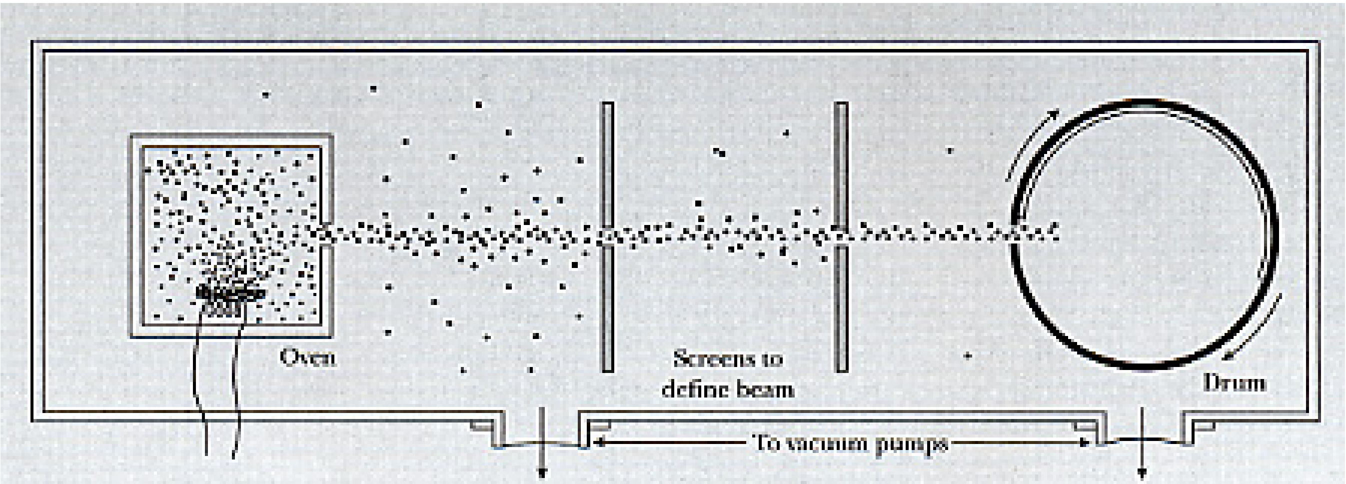
Distribution of Speeds

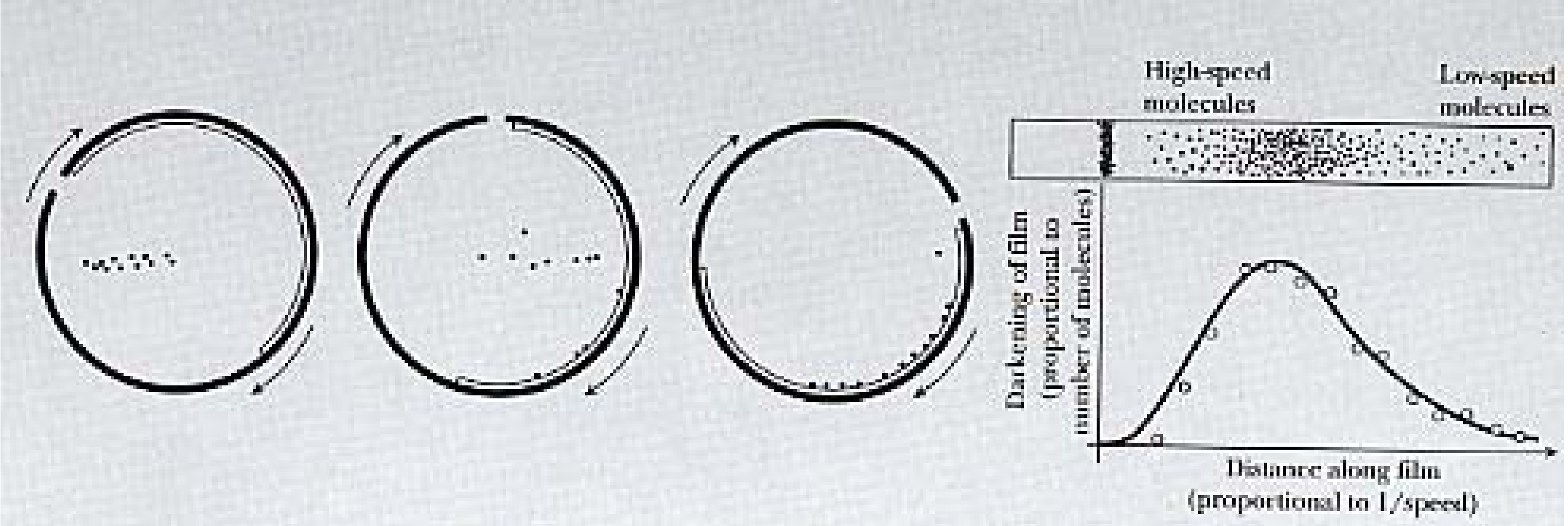


Effect of Changing T on the Distribution of Speeds



Measuring Molecular Speeds



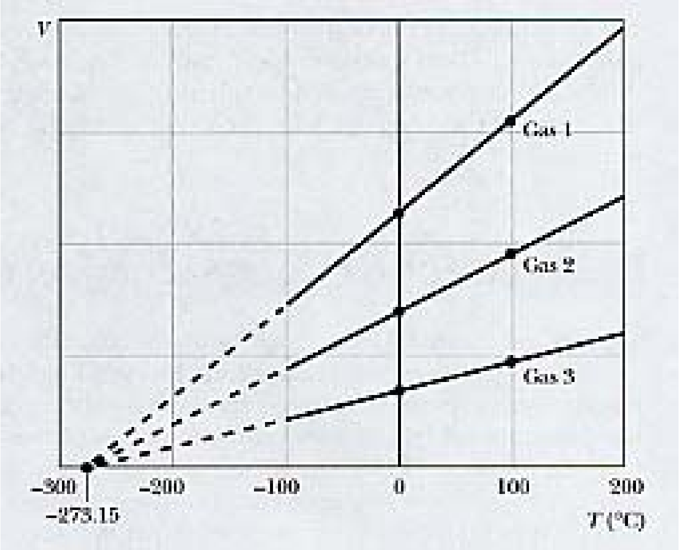


Gaseous Diffusion/Effusion

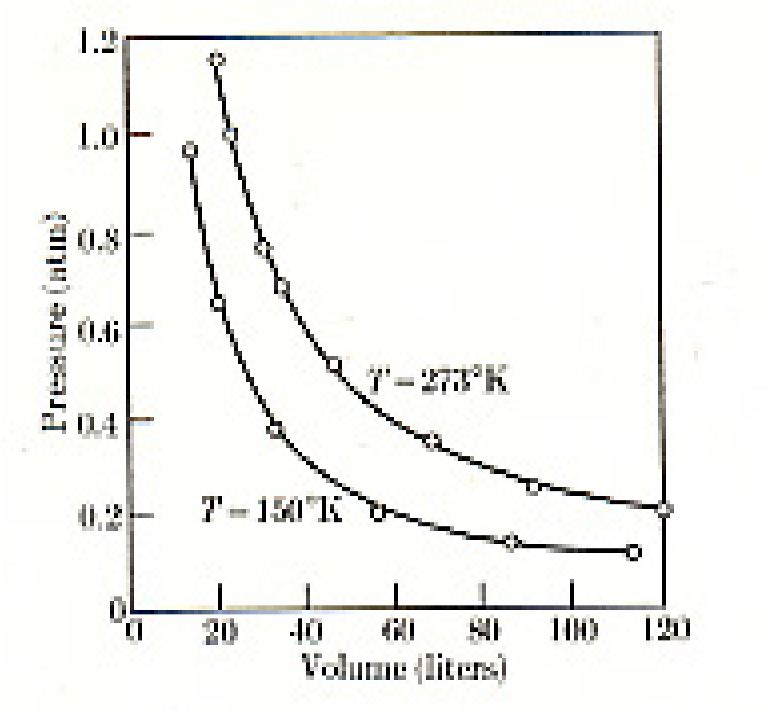
Diffusion of Ammonia and HCl

Effusion enrichment of UF_6

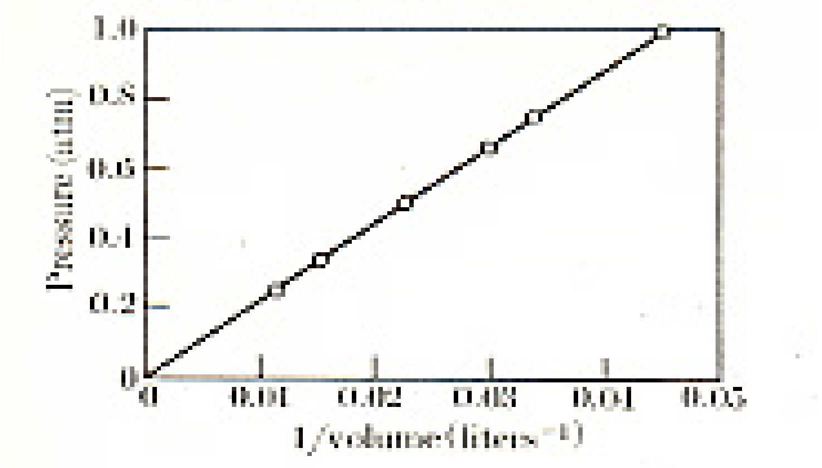
UF_6


V
Gas 1
Gas 2
Gas 3
−300
−200
−100
0
100
200
−273.15
T (°C)

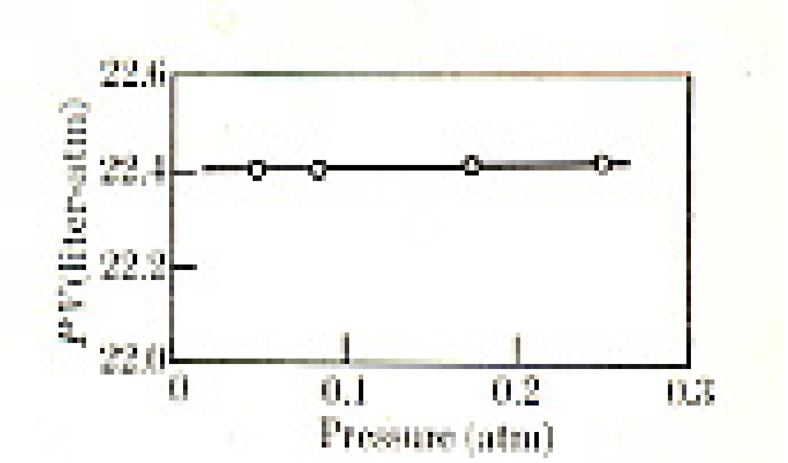
Boyle's Law



Pressure (atm)
1.2
1.0
0.8
0.6
0.4
0.2
0
T = 273°K
T = 150°K
0
20
40
60
80
100
120
Volume (liters)



Pressure (atm)
1.0
0.8
0.6
0.4
0.2
0
0
0.01
0.02
0.03
0.04
0.05
1/volume (liters^{-1})



PV (liter-atm)
22.6
22.4
22.2
22.0
0
0.1
0.2
0.3
Pressure (atm)

Homework

Homework Problem

COMBUSTION is central to the consumption of most power.

Significant Exceptions:
- Nuclear
- Geothermal
- Solar.

Natural gas can be burned for home heating or electric lighting and the chemistry looks like this:

$$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$$

Direct conversion (home heating)

Indirect conversion, via steam
to turbine electricity (lighting)

About 5-6 ounces of methane are required to provide enough heat for a comfortable bath for an average-sized adult in a tub appropriate in size for containing 20 gallons of water.

Do a Best Estimate/Good guess/Back-of-the-envelope approximate calculation to validate that assumption.

(1) To take 20 gallons of water
from say 15°C → 45°C

20 gal = 80 qt = 80 L = 80 kg = 80,000 g

sp. ht of water = 4.184 J/g/deg

heat = mass X sp. ht X ΔT

$$= (80,000\ \text{g})\left(\frac{4.184\ \text{J}}{\text{g deg}}\right)(45 - 15)\text{deg}$$

= 10,041,600 J

(2) Methane required to do that job:

$$(10{,}041{,}600\ \text{J})\left(\frac{1\ \text{mol}}{890\ \text{kJ}}\right)\left(\frac{1\ \text{kJ}}{1000\text{J}}\right) = 11.28\ \text{mol}$$

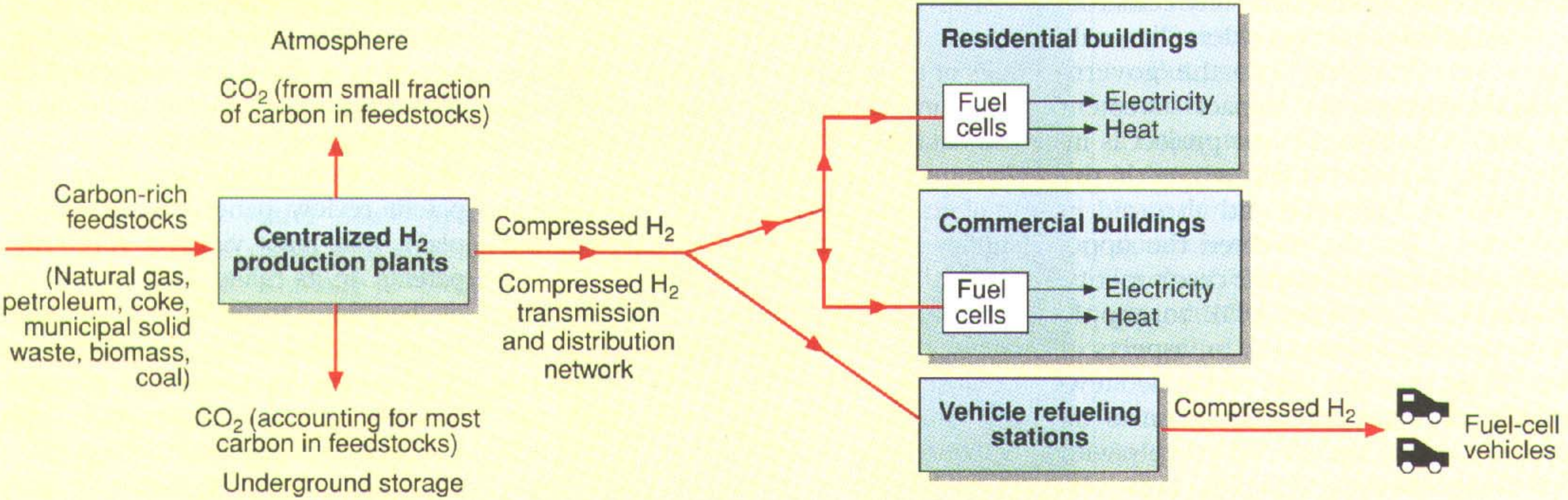
$$(11.3\ \text{mol})\left(\frac{16\ \text{g}}{1\ \text{mol}}\right)\left(\frac{1\ \text{lb}}{454\ \text{g}}\right)\left(\frac{16\ \text{oz}}{1\ \text{lb}}\right) = 6\ \text{oz}$$

.... or about 0.4 lb

.... or if propane (C_3H_8) is combusted, then about 2.5 ounces of fuel..... which means the heat of combustion of propane must differ from methane by a factor of .....

$$\left(\frac{6}{2.5}\right)\text{(890 kJ/mol)} = \text{2250 kJ/mol.}$$

Hydrogen energy system would release little carbon dioxide to the atmosphere



Atmosphere

CO_2 (from small fraction of carbon in feedstocks)

Carbon-rich feedstocks

(Natural gas, petroleum, coke, municipal solid waste, biomass, coal)

Centralized H_2 production plants

CO_2 (accounting for most carbon in feedstocks)

Underground storage

Compressed H_2

Compressed H_2 transmission and distribution network

Residential buildings

Fuel cells → Electricity

→ Heat

Commercial buildings

Fuel cells → Electricity

→ Heat

Vehicle refueling stations

Compressed H_2

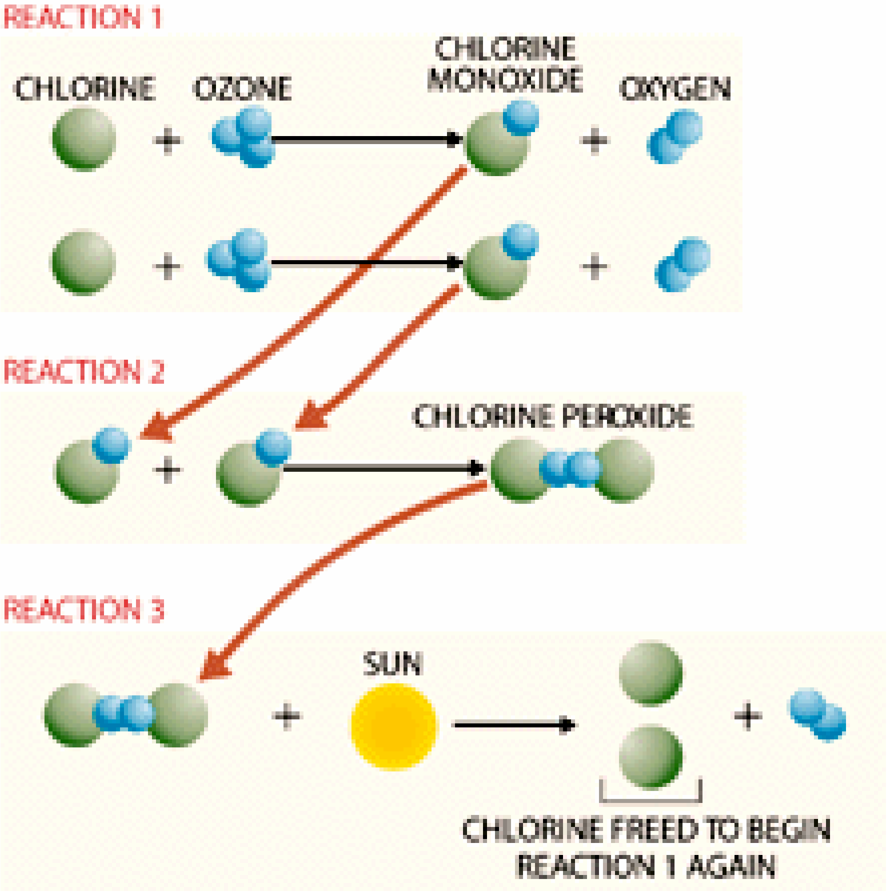
Fuel-cell vehicles

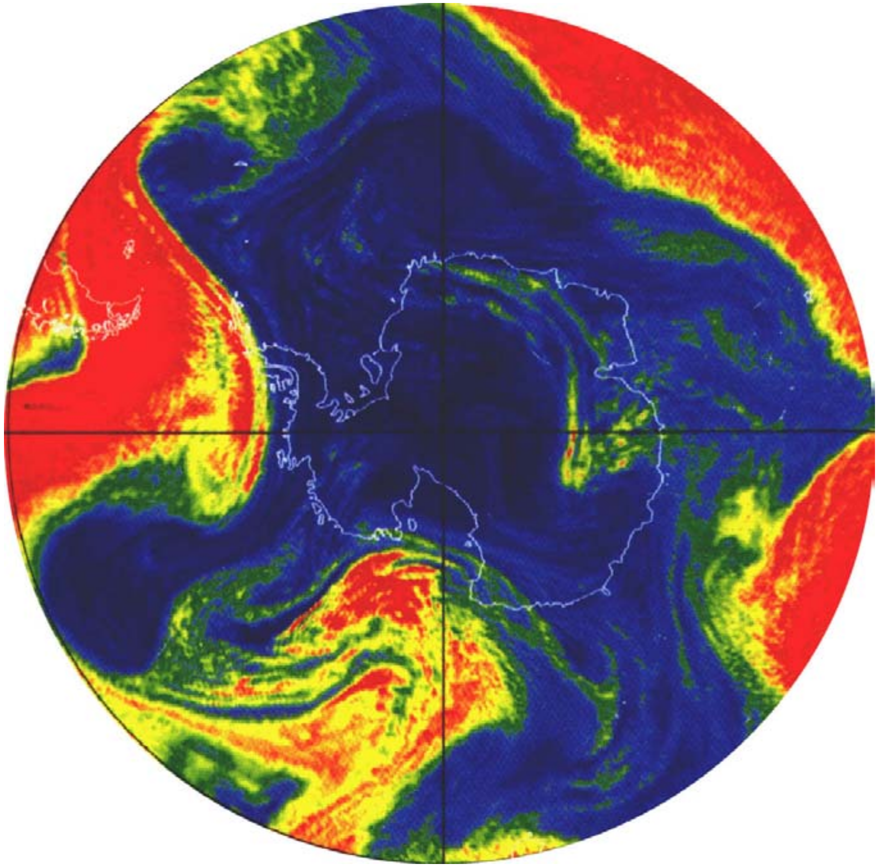
Source: Robert H. Williams

Chrysler Smart Car
Hybrid Vehicle

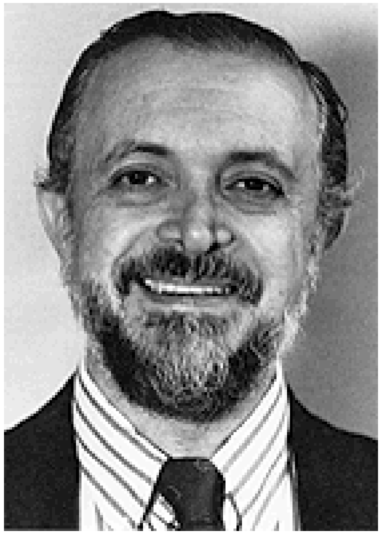
Chlorine Destroys Ozone

but is not consumed in the process





Crutzen



Molina

Rowland

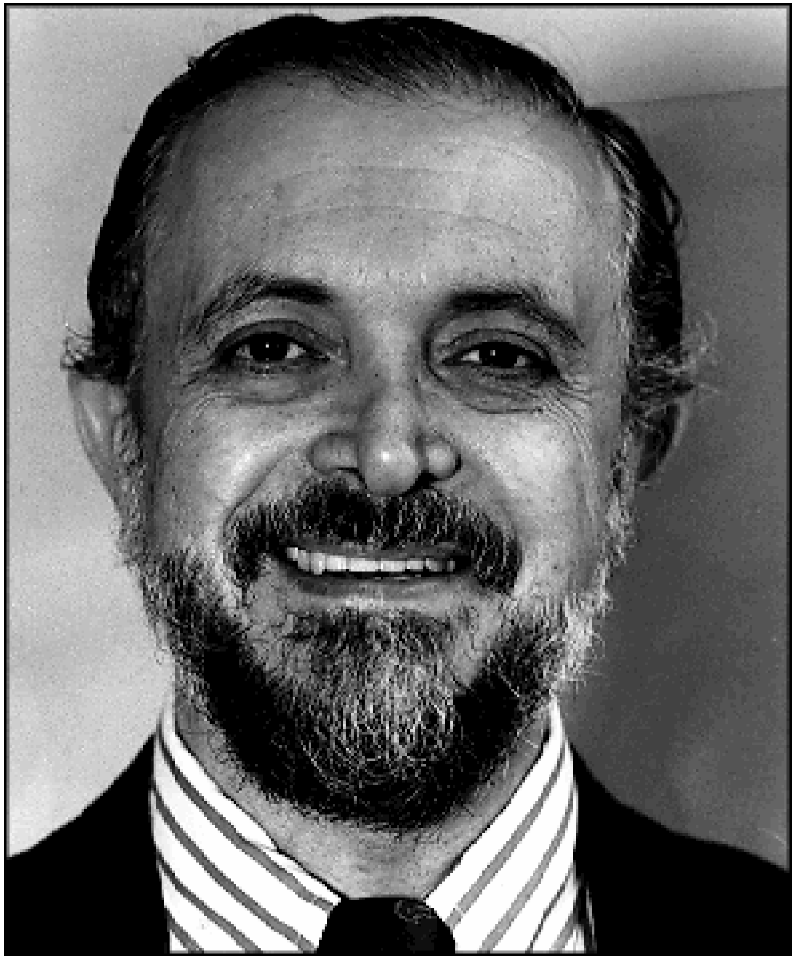
Paul Crutzen

Holland (The Netherlands)

Max-Planck-Institute for Chemistry
Mainz, Germany

1933 -

Mario Molina



USA (Mexico)

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1943 -**

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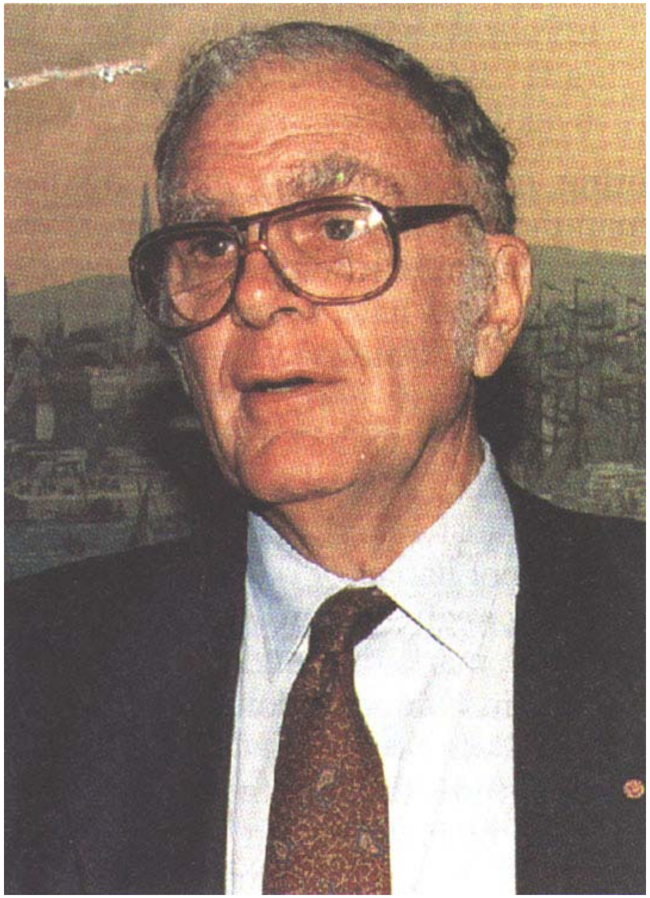

USA

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1927 -

Monday, November 3, 1997

Nearly a third of U.S. bridges rated deficient

But the money to fix them just isn't there, state officials say.

WASHINGTON -- Almost a third of the nation's bridges are dilapidated or too narrow or too weak to carry the traffic crossing them, federal records show.

By JONATHAN D. SALANT
The Associated Press