Focus 1:
The Properties of Gases

Perfect Gas Law

- Gases have predictable behavior ➔ useful to illustrate thermodynamic principles
- The state of a gas is described by 4 state variables

  (p, V, T, n)
- For a fixed n, only 2 of 3 state variables are truly independent
- The perfect gas equation of state can calculate the 3rd variable.

$$pV = nRT$$

p-V Isotherms

A plot of pressure vs volume for an ideal gas at a single temperature looks like this:

Partial Pressure

Partial pressure:

The portion of total pressure contributed by a gas in a mixture of gases

Dalton's Law:

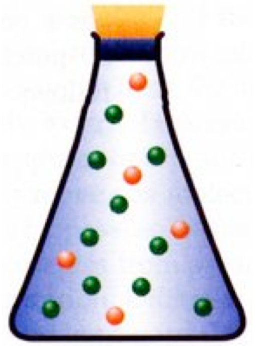
The total pressure is the sum of partial pressures of the individual gases.

Relationship between composition and partial pressure:

Partial Pressures

Suppose you have two 1 L containers at 298 K:

Container 1) 1 mole of ideal gas A mixed with 0.4 mole of ideal gas B



Container 2) 1 mole of ideal gas A

Which of the following conditions are true?

a) p_A in container 1 > p_A in container 2

b) p_A in container 1 < p_A in container 2

***c)* p_A in container 1 = p_A in container 2**

To text your answer, send 'OAOB A,B,etc' to (613) 777-0647

Units of Pressure

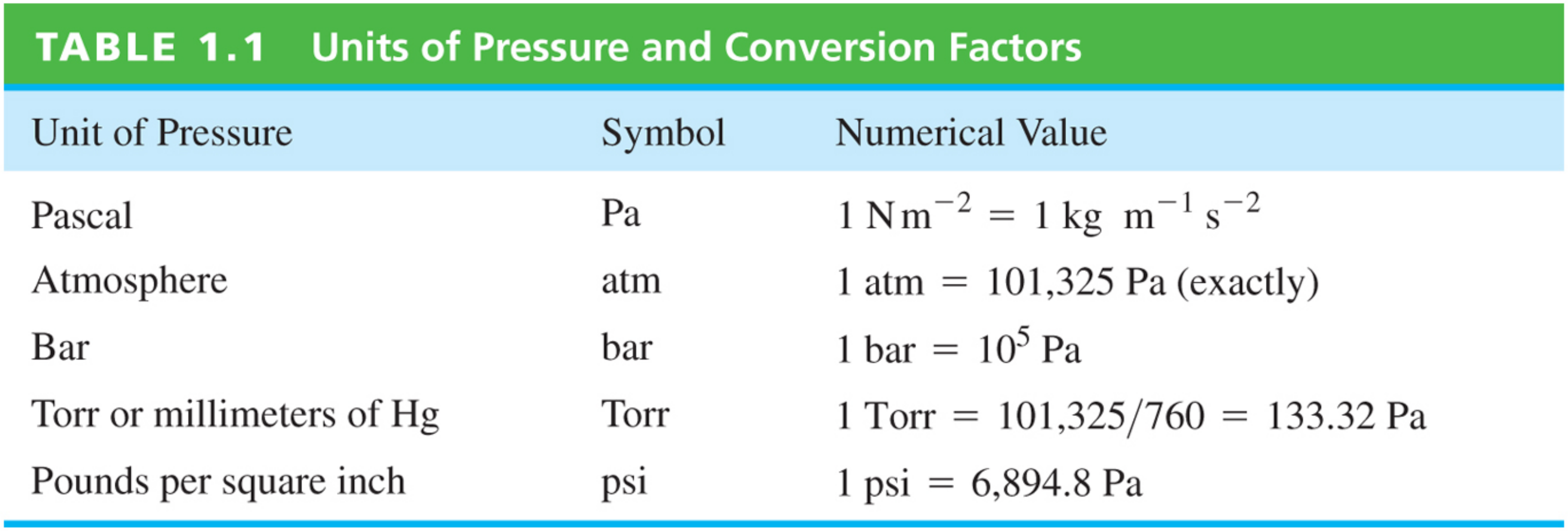


TABLE 1.1 Units of Pressure and Conversion Factors

Unit of Pressure	Symbol	Numerical Value
Pascal	Pa	$1\ \mathrm{N\,m^{-2}} = 1\ \mathrm{kg\ m^{-1}\ s^{-2}}$
Atmosphere	atm	1 atm = 101,325 Pa (exactly)
Bar	bar	1 bar = 10^5 Pa
Torr or millimeters of Hg	Torr	1 Torr = 101,325/760 = 133.32 Pa
Pounds per square inch	psi	1 psi = 6,894.8 Pa

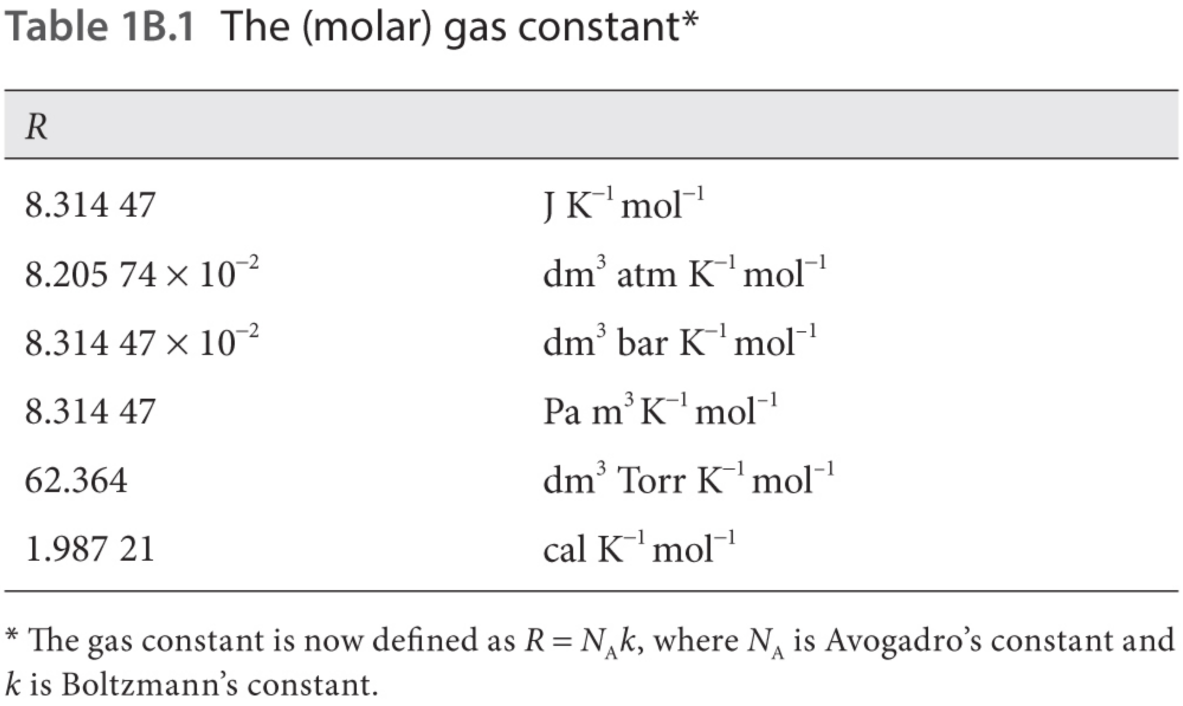


Table 1B.1 The (molar) gas constant*

R	
8.314 47	$\mathrm{J\ K^{-1}\ mol^{-1}}$
$8.205\ 74 \times 10^{-2}$	$\mathrm{dm^3\ atm\ K^{-1}\ mol^{-1}}$
$8.314\ 47 \times 10^{-2}$	$\mathrm{dm^3\ bar\ K^{-1}\ mol^{-1}}$
8.314 47	$\mathrm{Pa\ m^3\ K^{-1}\ mol^{-1}}$
62.364	$\mathrm{dm^3\ Torr\ K^{-1}\ mol^{-1}}$
1.987 21	$\mathrm{cal\ K^{-1}\ mol^{-1}}$

* The gas constant is now defined as $R = N_A k$, where N_A is Avogadro's constant and k is Boltzmann's constant.

But real gases are not ideal… are they…?

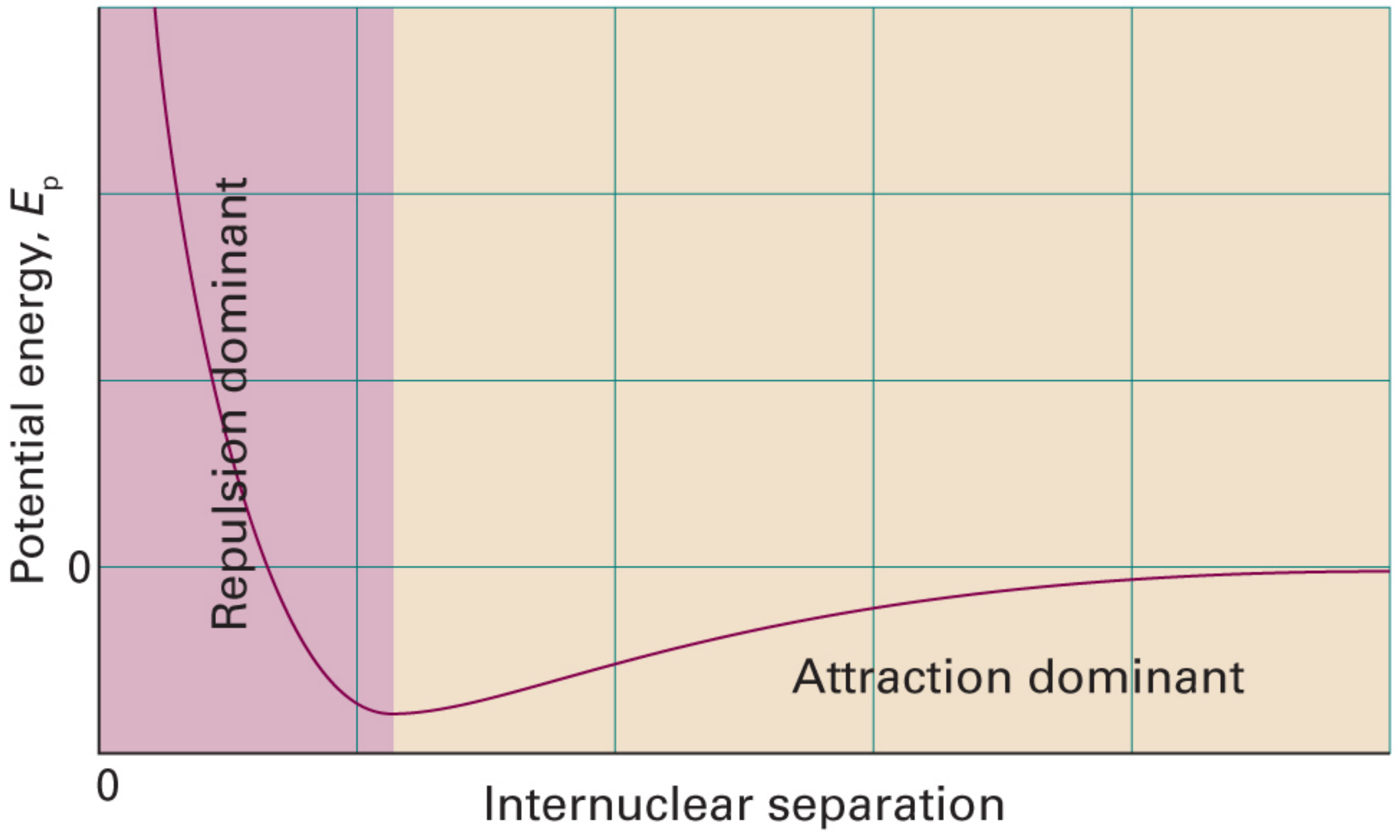
In fact:

***All* gases can obey the perfect gas laws so long as they are sufficiently dilute.**

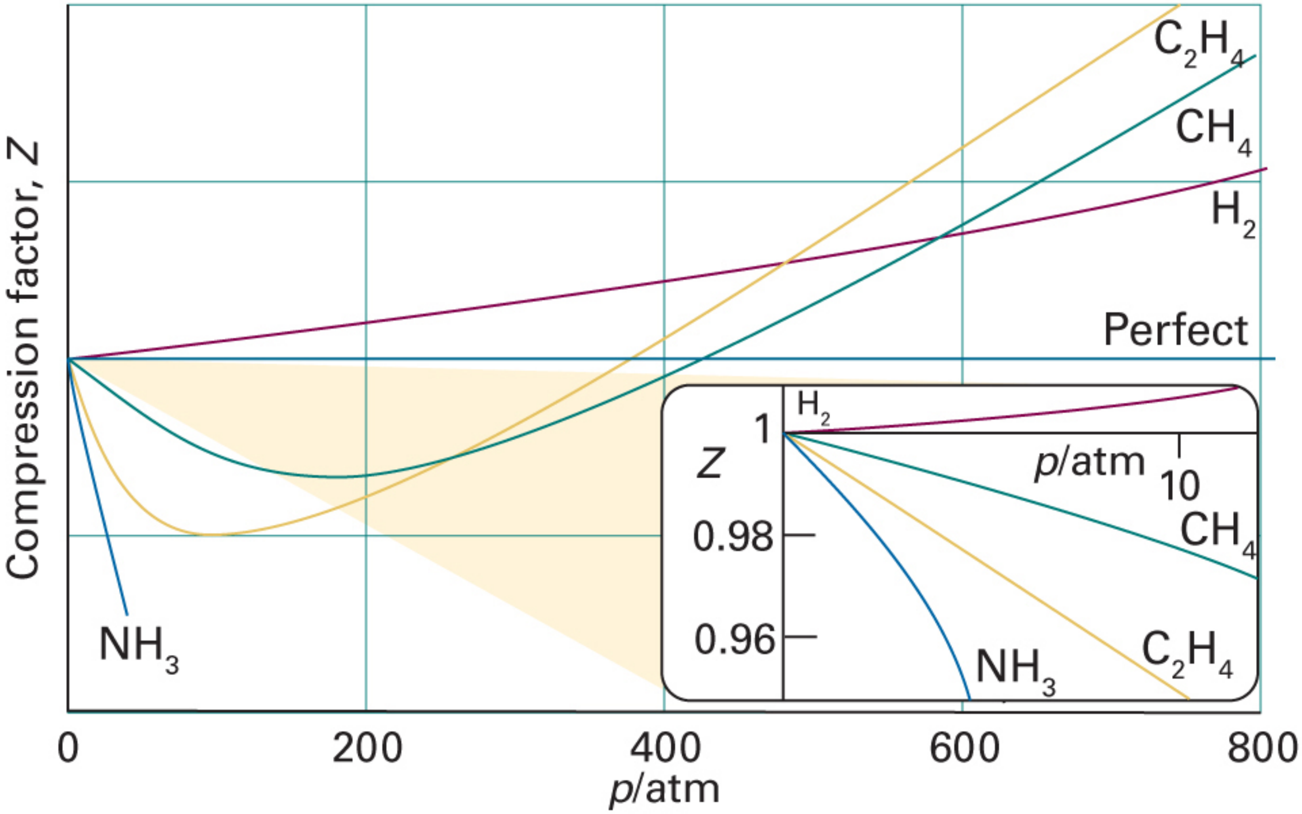
***All* gases tend to deviate from perfect behavior when they are more concentrated.**

What is the difference between a real gas and an ideal gas?

How do gas molecules interact?



Deviations from the Perfect Gas Law



What does the compression factor tell us?

Exercise C.7
A gas at 350 K and 12 atm has a molar volume 12 percent larger than that calculated from the perfect gas law. Calculate the compression factor and molar volume of this gas.

Attractive or repulsive interactions?

van der Waals Equation for Real Gases

The van der Waals equation accounts for repulsive and attractive interactions:

$$p = \frac{nRT}{V - nb} - a\left(\frac{n}{V}\right)^2$$

Van der Waals coefficients *a, b* are experimentally determined for each gas. (This means you have to be given this data to do calculation questions with the van der Waals equation!)

When to use the van der Waals Equation?

Almost never…!

Use it if you see any of the following in the question:

- **Real gas**
- **Van der Waals**
- **Values given for coefficients a and b**

Otherwise, use:

Recommended Exercises

Discussion Questions

D1C.1, D1C.3

Exercises

E1A1.1 – E1A1.3, E1A1.5 – E1A1.9, E1A.11
E1C.1, E1C.3, E1C.4

Problems

P1A.8, P1A.9, P1C.6

Property	Equation
Perfect gas law	$pV = nRT$
Partial pressure	$p_J = x_J p$
Mole fraction	$x_J = n_J/n$ $n = n_A + n_B + \cdots$
Compression factor	$Z = V_m/V_m^\circ$
van der Waals equation	$p = nRT/(V - nb) - a(n/V)^2$