Looking at Boyle’s Law (Compressibility of Gases)

Developing models that make sense for the behavior of gas volume as pressure changes
Looking at Boyle’s Law

Developing models that makes sense for the behavior of gas volume as pressure changes

“How is the gas pushing back?”
Objectives

Students will compare two possible models for the behavior of gases in the prior experiment.
A Coincidence?

Look at your experimental results

- Compare behavior of all gases
  - At the same temperature, all of the gases you studied had the same behavior.
  - If you started out with 25.0 mL of oxygen or 25.0 mL of methane, the addition of one, two, three, or four books, within experimental uncertainty, gave you the same volumes and thus the same graph.
  - Further studies would show that all gases, no matter their density, have the same compressibility!
Boyle's Law

For *all gases*, as pressure increases, volume decreases in the same way!
Score in the Gas Density Contest:
Bigger particles 1
More particles 0

More Mass
What is Happening?

You need to come up with a model of what is going on inside the syringe with these gases.

- **Empirical (Experimental) model:**
  - An imagined system that would explain the empirical observations.
  - A really good model not only explains, it also predicts.
  - A good model comes with a formula. The math helps you understand how the system works. The math also helps you make predictions.
An Infantile Model of an “Old” TV

Even small children make models of their world, intuitively

▪ How does this TV work?
  ▶ “There are people inside the TV”
  ▶ Model makes sense of some data
  ▶ But when a landscape comes up. . .
    – Baby begins to understand that the model does not explain *all* the data
    – Cars and big animals don’t fit
    – People are “scaled” to all sizes
    – Model is revised. . .

▪ The cable brings pictures like a water pipe!
Refining the model

The TV water pipe model

- The water pipe model is an improvement
  - It denies that there are people in the TV
  - It explains how so much information gets into the TV
  - It explains why the TV goes off when cable is “down”
  - But it doesn’t explain how the picture gets onto the viewing screen
Additional Refinements

Raster imaging

▪ The child looks closely at the screen
  ▶ He notices that the image is made up of dots of various colors, laid down in horizontal lines.
  ▶ He looks up the topic on the Internet or in a book and finds that electron “guns” fire electrons at the phosphorescent screen, moving rapidly across the screen to lay down the screen images.
  ▶ This process is called raster imaging.
  ▶ But the child still has more work to do before he can “build” a TV screen.
Modeling P-V behavior

Can you construct a physical model that makes sense?

- Model 1:
  - A model that explains how it is that an increase in pressure is accompanied by a reduction in volume of a gas.
  - A model that makes sense in terms of a common physical system, easily visualized.
  - A model that approximates the data mathematically, within certain limits.
Yes, the one and only

A Viacom trademark
The Sponge Model

Does it explain pressure-volume behavior?

- Within limits, it does
The Sponge Model

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  - As you increase pressure, the volume goes down.
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  ▸ As you increase pressure, the volume goes down.
  ▸ When you reduce the pressure, the volume goes up.
The Sponge Model

Does it explain pressure-volume behavior?

▪ Within limits, it does
  ▶ As you increase pressure, the volume goes down.
  ▶ When you reduce the pressure, the volume goes up.
  ▶ As the volume gets very small, resistance to further compression gets very large.
  ▶ It could explain density variations in gases.

▪ However...
The Sponge Model

Where it falls short

- Outside limits
  - The sponge will not expand into any volume as a gas will when pressure gets really small.
  - The sponge takes up a finite volume beyond which it cannot be compressed.
  - After a period of time, the sponge collapses under pressure.
  - The sponge is visible; gases, unless they absorb light, cannot be seen.
Kinetic Molecular Theory

Let’s consider this as an improved model

- KMT says gases are …
  - made up of small particles, called atoms or molecules.
  - quite invisible and in constant, rapid, random motion, never slowing down as long as the temperature stays the same.
  - collide with the walls of a container, imparting force and thus showing a pressure.
Change Pressure

- Push in the plunger
  - Molecules don’t move faster but collide more frequently as walls get closer together; pressure increases and volume decreases.
  - Frequency of collisions and pressure should double as volume is cut in half.
  - So if $P_1 = 1$ unit and $V_1 = 1$ unit, we would expect when $P_2 = 2$ units, that $V_2$ would be $\frac{1}{2}$ unit.
Assumptions

Or it won’t work

- Assume in kinetic molecular theory
  - Somehow the gas molecules on the whole are not slowing down.
  - Or else the piston would gradually collapse.
  - We suspect that the constant temperature has something to do with this, but will look at that in later experiments. If no energy is being lost in the collisions, the physicists tell us that these collisions are perfectly elastic, like billiard balls clicking.
Can we “prove” that there are gas particles and that differences in density are caused by different sized particles?

Yes, and in 1811, using the work of other scientists, Amadeo Avogadro showed us how to count particles we can't see, using the chemical reactions of gases at the same temperature and pressure.