

# FUGACITY

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I DON'T  
UNDERSTAND  
FUGACITY.

I'M NOT  
SURPRISED!

FUGACITY IS A  
STRICTLY THEORETICAL  
THERMODYNAMIC CONCEPT  
THAT MOST PEOPLE HAVE  
TROUBLE GRASPING- SO  
DON'T WORRY, YOU'RE  
NOT ALONE!

BUT IF YOU  
CAN FOCUS ON THE  
BASIC CONCEPT AND  
HOW IT IS APPLIED, IT  
SHOULD BECOME A  
LOT CLEARER!

FIRST,  
LET'S TALK  
ABOUT WHAT  
FUGACITY  
ISN'T.  
  
IT'S NOT A  
PROPERTY THAT YOU  
CAN DIRECTLY MEASURE,  
THAT YOU CAN SEE, OR THAT  
YOU CAN IMMEDIATELY KNOW  
WITHOUT KNOWING OTHER  
PROPERTIES ABOUT YOUR  
SYSTEM AND CHEMICAL  
SPECIES.

THAT'S  
WHY IT SEEMS  
LIKE SOME KIND OF  
THEORETICAL NON-  
SENSE!

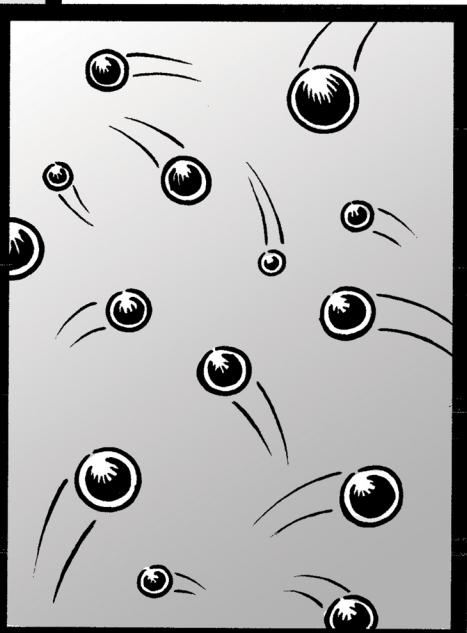
WELL,  
SURE -- IF YOU  
ONLY FOCUS ON THE  
TIME YOU SPEND TO  
CALCULATE IT.



SO WHAT ***IS*** FUGACITY? WELL, LET'S CONSIDER A CLOSED SYSTEM CONTAINING SEVERAL DIFFERENT SPECIES.

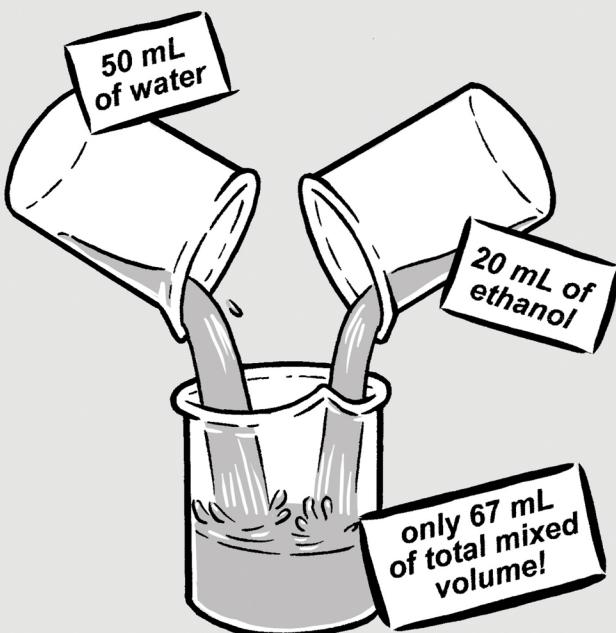


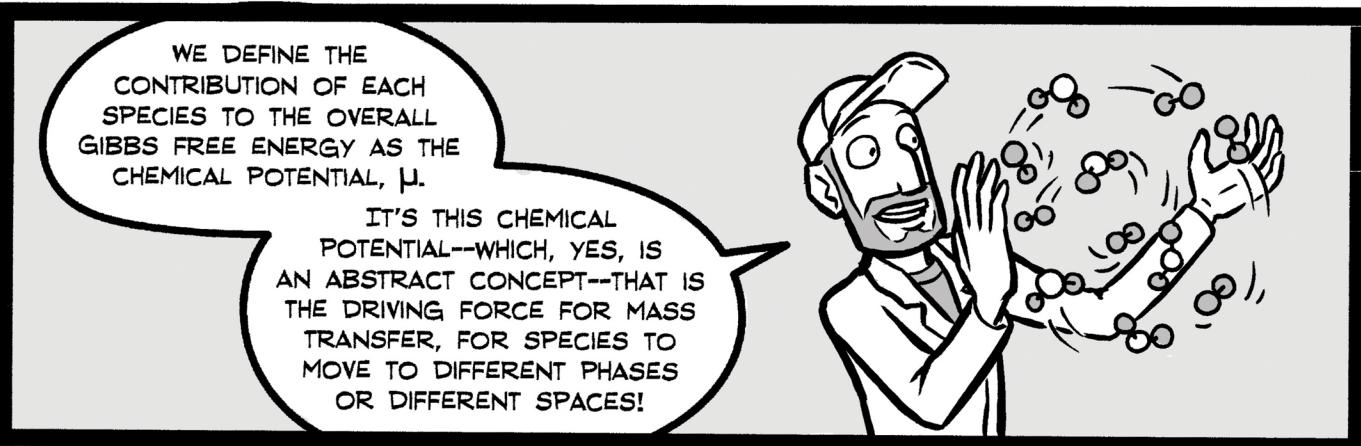
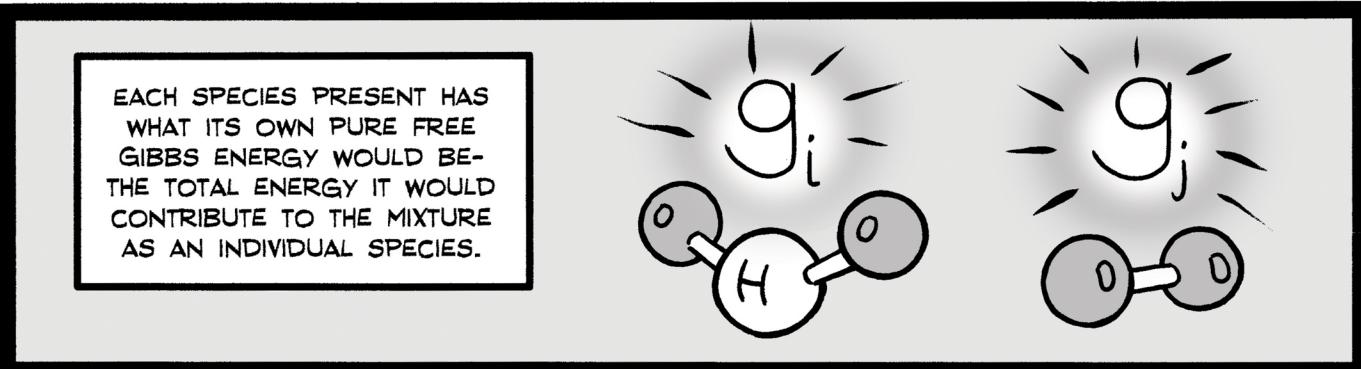
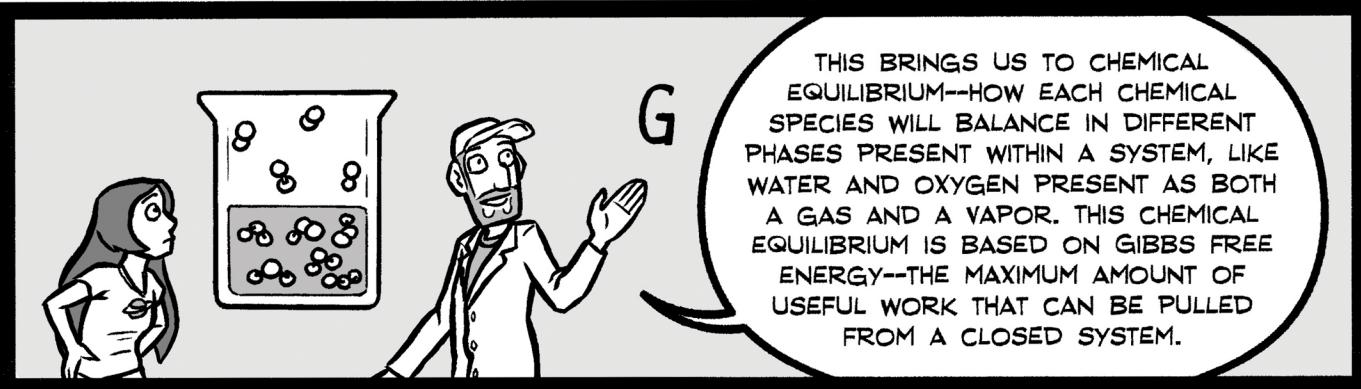
INSIDE, EACH SPECIES TAKES UP ITS OWN VOLUME AND EXERTS ITS OWN PRESSURE, BOTH OF WHICH ARE FRACTIONS OF THE WHOLE, RIGHT?



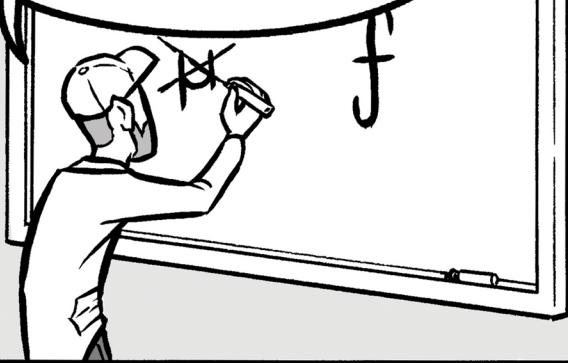
WELL, IF WE TREAT EACH CHEMICAL SPECIES AS IDEAL, WE WOULD ASSUME THAT EACH SET OF MOLECULES TAKE UP SPACE WITHOUT INTERACTING WITH EACH OTHER--SOMETHING WE KNOW IS NOT REALISTICALLY TRUE!

IN REALITY, THE PRESENCE, MOVEMENT, AND ACTIVITY OF EACH MOLECULE--AS WELL AS THE ATTRACTIONS BETWEEN DIFFERENT MOLECULES - WILL AFFECT ALL THE OTHER MOLECULES PRESENT! THIS INTERACTION AFFECTS THE PRESSURE AND VOLUME AND CHANGES THE OVERALL CONDITIONS WITHIN THE SYSTEM.





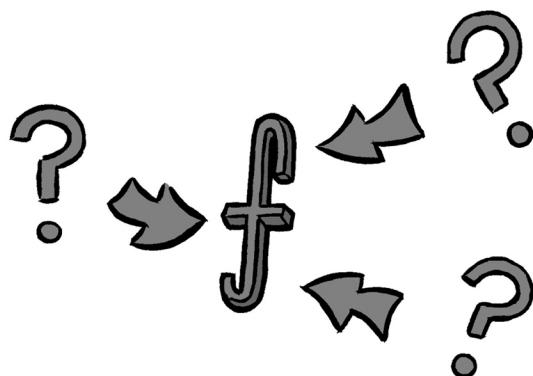
CHEMICAL POTENTIAL IS A PAIN TO WORK WITH MATHEMATICALLY. BASED ON ITS DEFINITION, FOR CERTAIN CASES LIKE INCREDIBLY SMALL CONCENTRATIONS IN A MIXTURE, CHEMICAL POTENTIAL BECOMES USELESS.



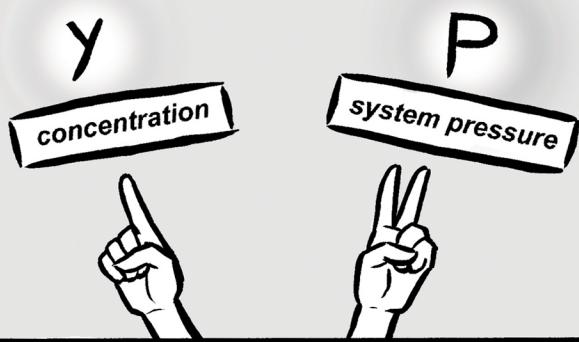
WHICH BRINGS US TO FUGACITY. IT'S RELATED TO CHEMICAL POTENTIAL, BUT CAN BE USED WITH GASES, LIQUIDS, OR SOLIDS TO HELP CHARACTERIZE CHEMICAL EQUILIBRIUM!



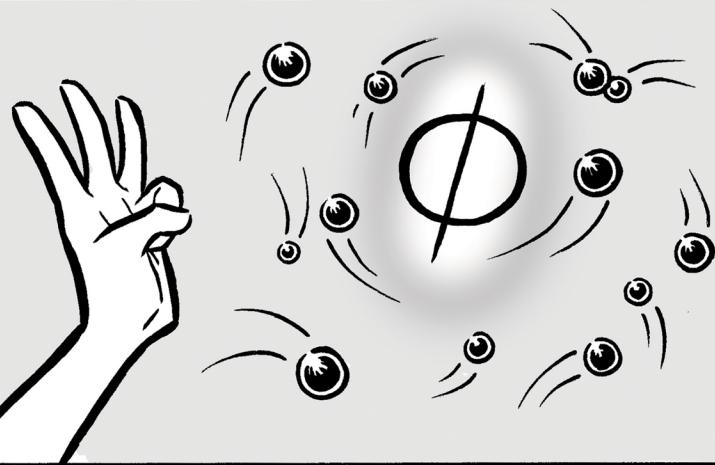
THINK OF FUGACITY AS "CORRECTED PRESSURE." EACH CHEMICAL SPECIES CAN BE DETERMINED FROM THE PRODUCT OF THREE COMPONENTS.



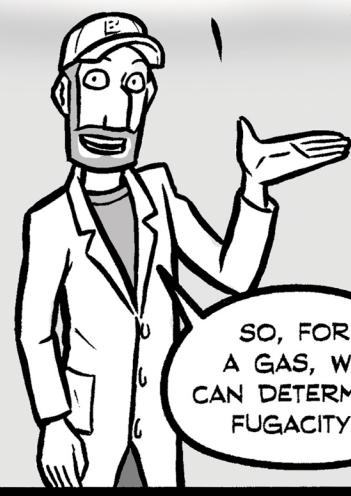
FOR A GAS, WE TAKE THE SPECIES' CONCENTRATION AND THE SYSTEM PRESSURE--THAT COMBINATION ALONE DESCRIBES THE PARTIAL PRESSURE THAT EACH SPECIES NORMALLY TAKES UP WITHIN THE ENTIRE SYSTEM'S PRESSURE.



BUT THERE'S A THIRD COMPONENT: A COEFFICIENT TO DESCRIBE HOW IDEAL THE SPECIES IS BEHAVING! HERE IS WHERE THOSE INTERSPECIES INTERACTIONS MATTER SO MUCH! FOR A GAS, THIS COEFFICIENT IS APTLY NAMED THE FUGACITY COEFFICIENT.

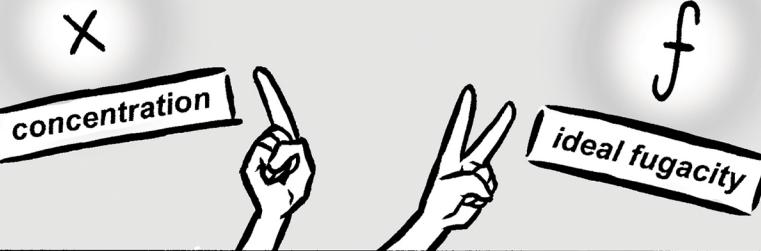


$$\hat{f}_i = y_i \phi_i^v P$$



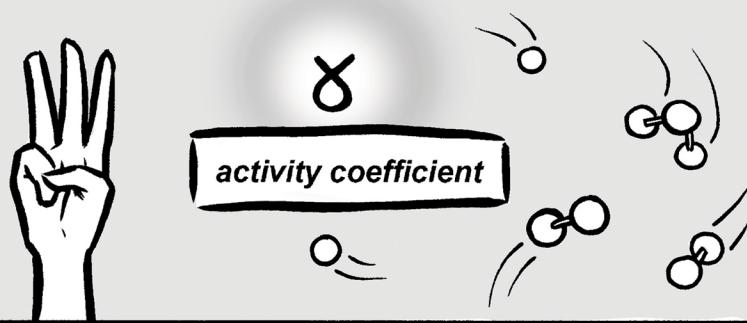
SO, FOR A GAS, WE CAN DETERMINE FUGACITY!

FOR A LIQUID OR A SOLID, IT'S A LITTLE DIFFERENT. WHILE FUGACITY IS STILL A COMBINATION OF CONCENTRATION, AN IDEALITY COEFFICIENT, AND PRESSURE, YOU NEED TO REMEMBER THAT PRESSURE IS EXERTED A LITTLE DIFFERENT ON LIQUIDS AND SOLIDS THAN ON GASES.



SO WHILE CONCENTRATION IS STILL A FACTOR, INSTEAD OF PRESSURE, THE CONTRIBUTING COMPONENT IS THE "IDEAL FUGACITY," WHICH CAN BE DETERMINED AS THE FUGACITY OF THE SPECIES WHEN IT IS A PURE SPECIES.

FOR LIQUIDS AND SOLIDS, THAT COEFFICIENT SPECIFICALLY DESCRIBING IDEALITY IS THE ACTIVITY COEFFICIENT - AGAIN, DESCRIBING THE ACTIVITY OF THE CHEMICAL RELATIVE TO AN IDEAL STATE.



SO WE HAVE FOR A LIQUID:

$$\hat{f}_i^l = x_i \gamma_i f_i^l$$

AND FOR A SOLID:

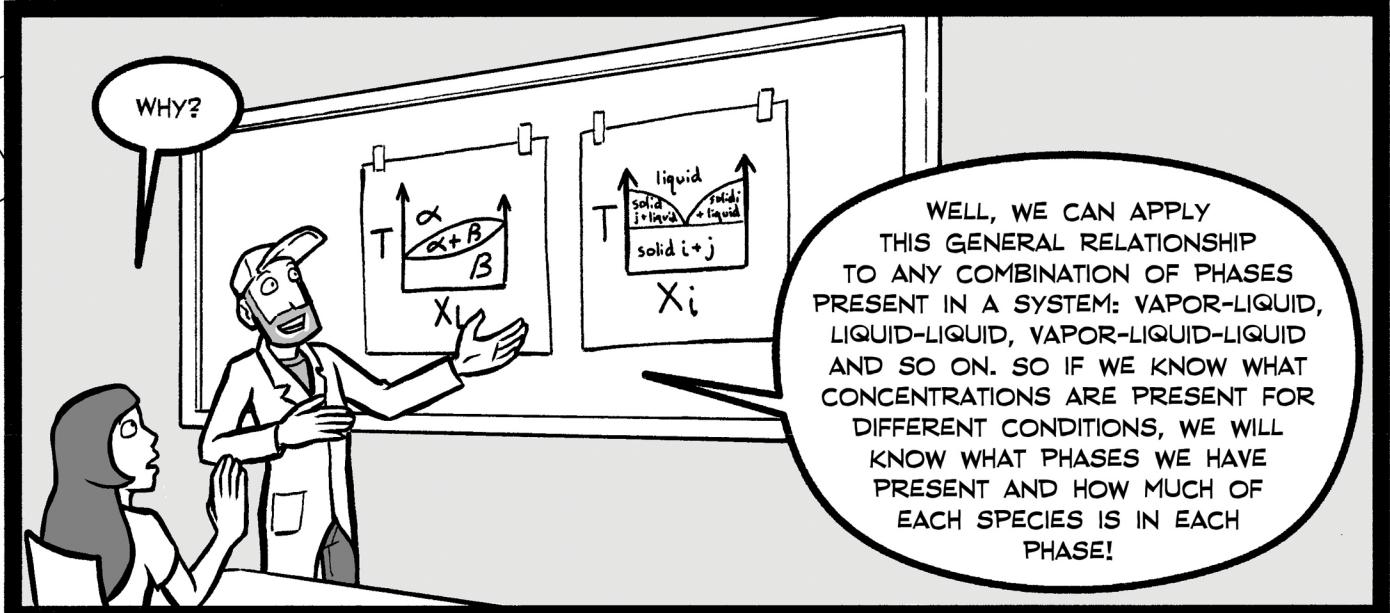
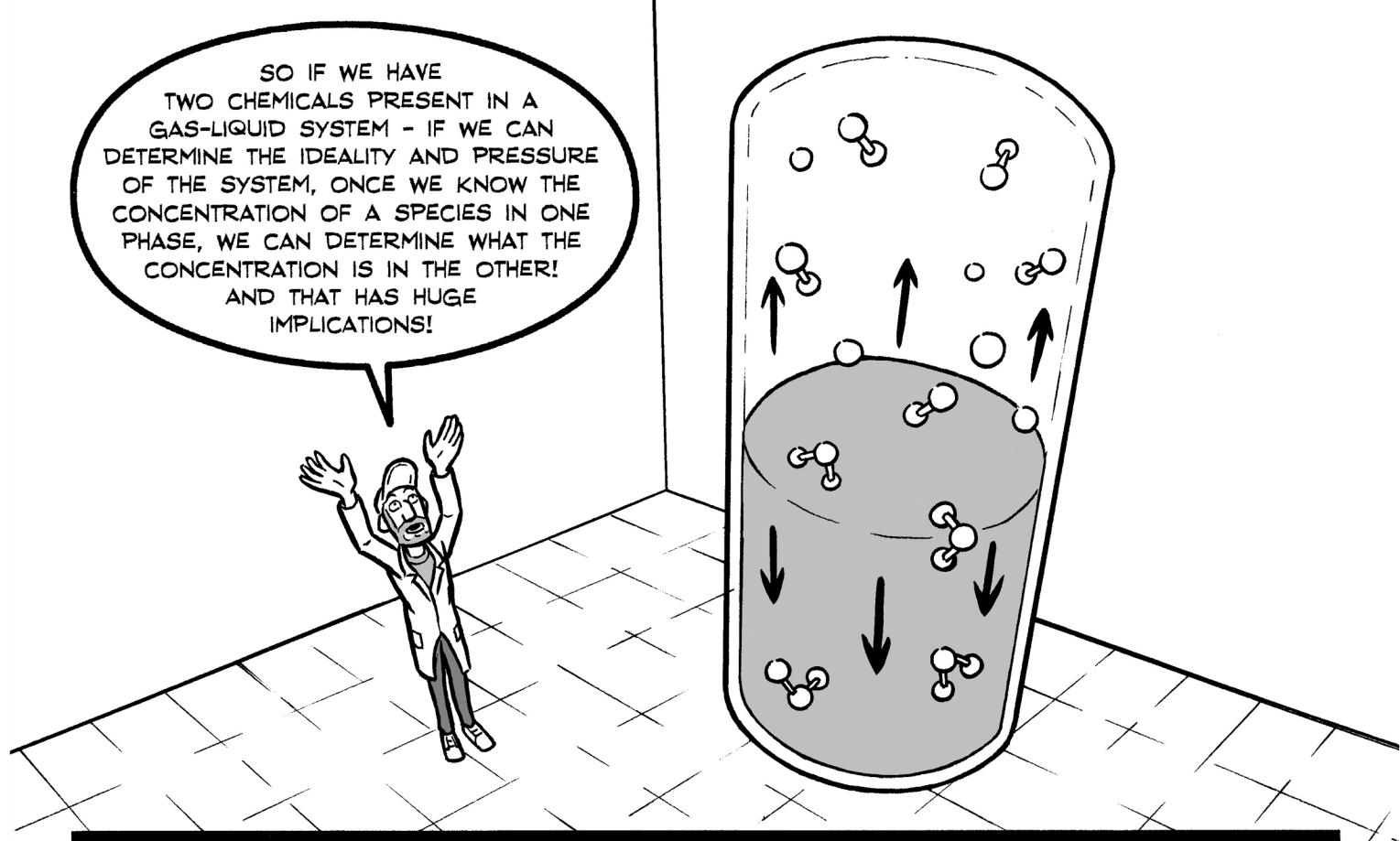
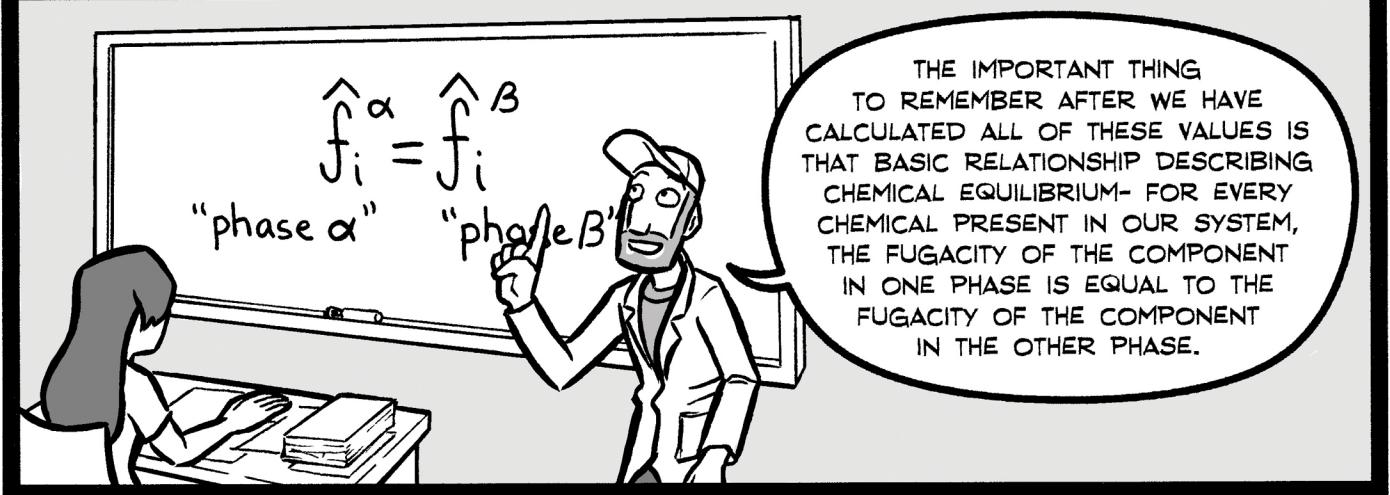
$$\hat{f}_i^s = X_i \Gamma_i f_i^s$$



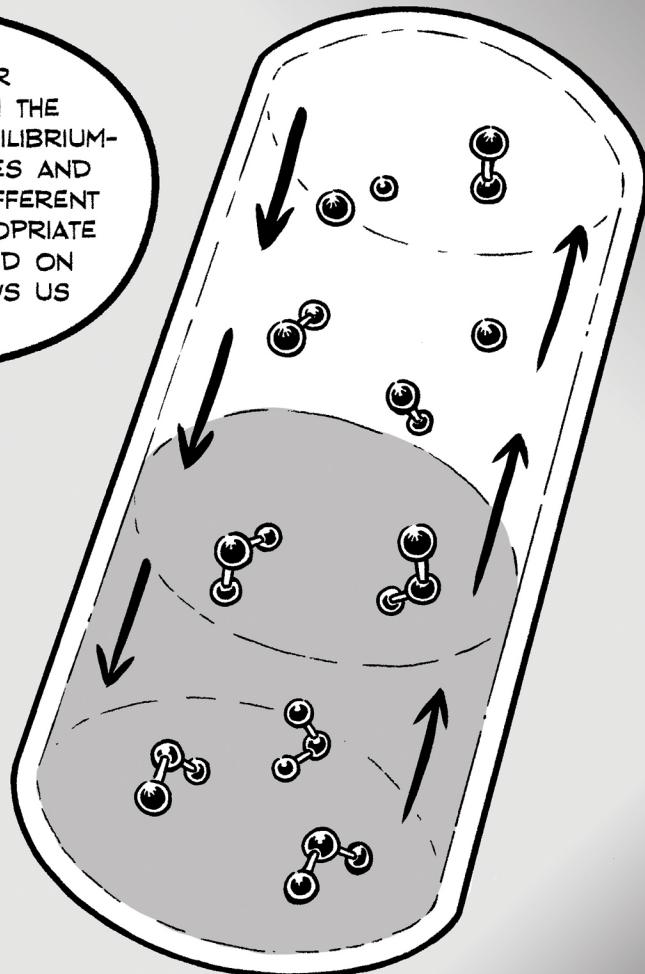
THAT'S NOT WHAT YOU'RE REALLY ASKING. YOU'RE ASKING, WHY DOES THIS EVEN MATTER, RIGHT?

WELL, YES.

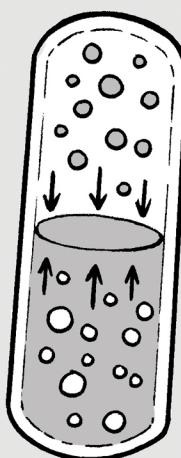




WHICH IS USEFUL IN REAL-WORLD APPLICATIONS! FOR EXAMPLE, DISTILATION IS BASED ON THE ENTIRE CONCEPT OF VAPOR-LIQUID EQUILIBRIUM--WE APPLY A RANGE OF TEMPERATURES AND PRESSURES TO BE ABLE TO DRIVE DIFFERENT SPECIES APART--AND KNOWING APPROPRIATE RANGES OF CONCENTRATIONS, BASED ON OUR FUGACITY RELATIONSHIP, ALLOWS US TO OPTIMIZE OUR SYSTEM.



WE HAVE SIMILAR RELATIONSHIPS FOR ABSORPTION OF GAS PARTICLES ON A SOLID FILTER SURFACE, OR THE SEPARATION OF CHEMICALS IN IMMISCIBLE LIQUID PHASES--WORKING WITH THE CHEMICAL EQUILIBRIUM EQUATION PRODUCED BY FUGACITY, WE CAN DETERMINE THE OPTIMAL OPERATING CONDITIONS.



LET'S LOOK AT SOME EXAMPLES. FIRST, CONSIDER A CASE WHERE WE'VE GOT MIXTURES IN TWO DIFFERENT BEAKERS SEPARATED BY A VALVE. ONE SIDE HAS JUST A LITTLE BIT OF A PURE SUBSTANCE (WE'LL CALL IT A,) WHILE THE OTHER SIDE IS A LOT OF A 95% A/5% B MIXTURE.



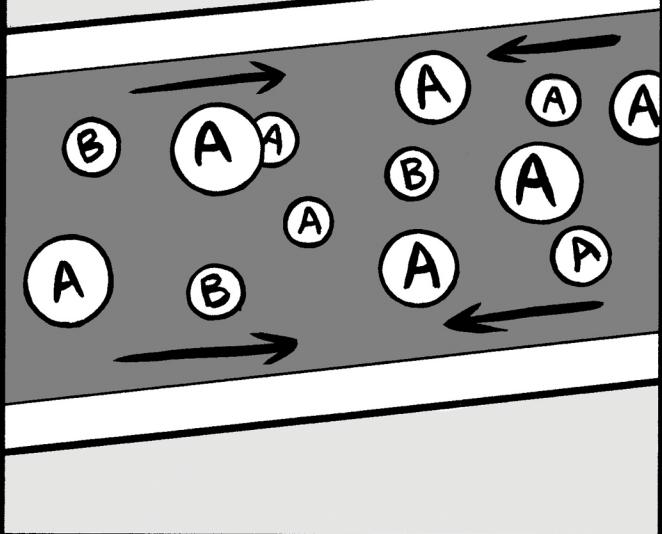
WHEN I OPEN THE VALVE, WHICH DIRECTION WILL A AND B PARTICLES TRAVEL?



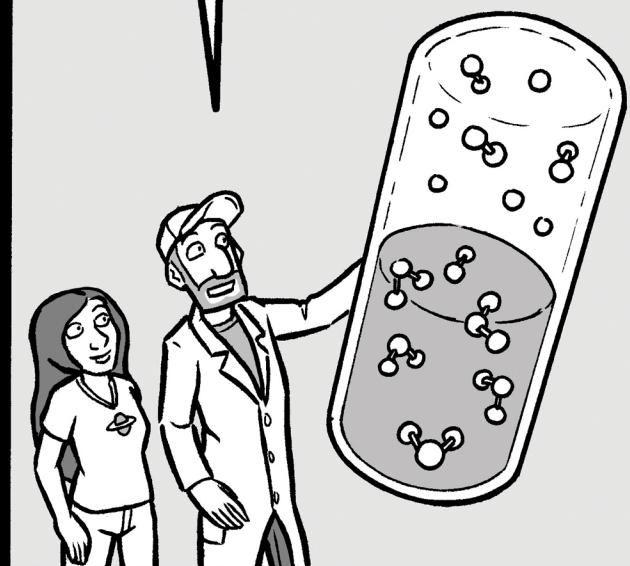
WOULDN'T THEY BOTH GO FROM THE SIDE WITH THE LARGER VOLUME TO THE SIDE WITH LESS?



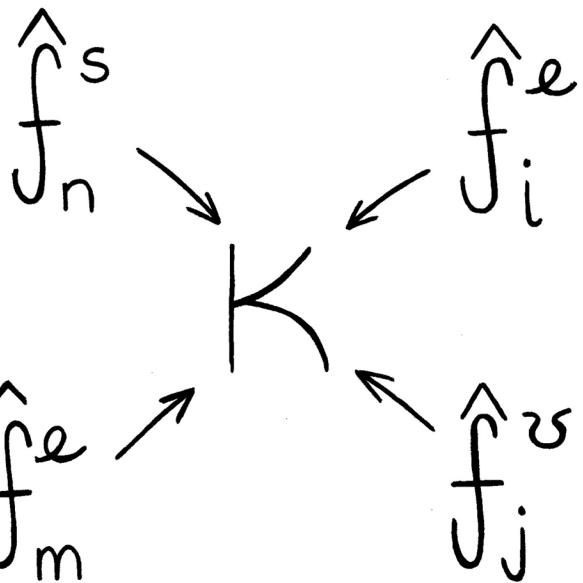
SO EVEN THOUGH THE SIDE WITH THE MIXTURE HAS FAR MORE A IN TERMS OF VOLUME THAN THE PURE SIDE, WHILE PARTICLES OF B TRAVEL FROM THE MIXED SIDE TO THE PURE SIDE, PARTICLES OF A WILL TRAVEL FROM THE PURE SIDE TO THE MIXTURE!



SIMILARLY, BY CALCULATING THE FUGACITY FOR DIFFERENT TEMPERATURES AND PRESSURES, WE CAN DETERMINE WHAT CONCENTRATIONS WE WILL HAVE AND HOW WELL OUR SYSTEMS ARE MIXING OR SEPARATING!



BUT IT GOES FURTHER- THE TERM FOR CHEMICAL EQUILIBRIUM, K, IS DEPENDENT ON THE PRODUCT OF ALL FUGACITIES OF ALL SPECIES PRESENT IN A SYSTEM.



SO?

SO, THIS MEANS THAT IF WE CAN CALCULATE THE FUGACITY FOR EACH COMPONENT IN A REACTIVE SYSTEM, THEN WE CAN DETERMINE WHAT THE OUTPUT CONCENTRATION WILL BE FROM A REACTOR! SO THROUGH FUGACITY, WE CAN ACTUALLY DETERMINE HOW EFFECTIVELY A REACTOR IS WORKING AND HOW MUCH OF OUR DESIRED PRODUCT IS BEING PRODUCED!



