

## Week 2 Questions, summarized!

1. Is homework generally going to be due on Thursdays?

Nope – but often!

2. When doing the first homework I came across ppt by mass and ppt by volume. Is there a way to convert between the two easily that I haven't figured out?

Yes – the simple way is to multiply the volume mixing ratio by the ratio of molecular weight of “X” to the average molecular weight of air (“M”). So for CO<sub>2</sub>, this ratio is 44/29. For O<sub>2</sub> it's 32/29, etc. So if you have 400 ppm of CO<sub>2</sub> (or 0.04% mole fraction), you have 0.61 grams CO<sub>2</sub> per kg of air. I'm not sure what the best way would be to write this – it's not that common – maybe “610 parts per million by mass?” We ought to check.

3. Are there sinks in the ocean for the CO<sub>2</sub> (i.e., inorganic carbon) that is absorbed from the atmosphere?

Answer – yes. There are both biogenic (i.e., photosynthesis) and inorganic (i.e., sedimentation) sinks for dissolved CO<sub>2</sub>. Plankton will convert the CO<sub>2</sub> near the surface into organic carbon, reducing the dissolved CO<sub>2</sub>, creating a gradient between the atmosphere and the surface ocean. This acts as a “pump” to pull more CO<sub>2</sub> from the air. As for inorganic carbon (carbonate), in the presence of high abundances of calcium, carbonate ion (CO<sub>3</sub><sup>2-</sup>) will react to form calcium carbonate, which is used by animals to form shells. These can fall to the bottom of the ocean and be buried (as can dead fleshy animals).

4. Does air pollution decrease in the wet seasons when there is more deposition?

Probably, but I am not up to date on the models results that are probably needed to make this case. It's probably dependent on location. Rainier places are probably cleaner, as long as there isn't some change in the emission sources that would offset the deposition. Also, it is important to consider local meteorological circumstances.

5. In the Paul Monks Atmospheric Chem - 1 youtube video, he talks about the lifetime of different chemicals in the atmosphere, such as methane which has a lifetime of 9.3 years. How are scientists able to quantify the numbers for the lifetime of chemicals in the air?

There are many ways to get at the issue of the lifetime of a particular chemical, and there are multiple definitions. The two most useful definitions for this class are the lifetime with respect to reaction with some oxidant, such as OH, and the actual “residence time” in the atmosphere. Sometimes these two quantities are nearly the same, as in the case of the loss of a compound that reacts with only one species, like OH, and has no other ways to be removed from the atmosphere. The residence time for a molecule that has multiple removal processes can be much shorter than the reactive lifetime. So for species like nitric acid, sulfuric acid, etc. that can rainout, the residence time could be on the order of hours to days even if the chemical lifetime is quite long. We will talk about other ways chemicals can be removed from the atmosphere over the course of the semester.

6. What are the common units used for expressing physical values/data in atmospheric chemistry/science? Such as, what is the most common unit for mass, length, concentration, volume, etc...

If only there were common units! This is an issue that makes atmospheric chemistry confusing to many people. Let's just say that it's kind of like learning a foreign language at times! I'll do my best to keep things sane.

7. Inspired by this week's homework questions, could you explain consumer gasoline octane ratings and discuss a bit of the chemistry of combustion?

We'll get into the combustion chemistry soon – stay tuned! As for explaining octane ratings, Wikipedia does a decent job.

[https://en.wikipedia.org/wiki/Octane\\_rating](https://en.wikipedia.org/wiki/Octane_rating)

8. Can you share with us any more intense, brief pollution events similar to the London events presented by the video watched in class?

Obviously, this phenomenon occurred a lot when I was growing up in Los Angeles – during the 1960s and 1970s. And, these days, China has multiple cities with dreadful pollution events. Mexico City, etc.

9. We know there is a considerable amount of O<sub>2</sub> in the atmosphere and we also know that oxygen radicals are responsible for a lot of interesting atmospheric chemistry – how do oxygen radicals form/are they introduced into the atmosphere?

There are several ways to interpret this question – from the point of view of overall oxygen (since O<sub>2</sub> is a radical, meaning that it has unpaired electrons), O<sub>2</sub> is mainly produced by photosynthesis. Of course, the ultimate source of O<sub>2</sub> is (or was) water and rocks! But you might also be asking about other forms of oxygen, like OH, O, and O<sub>3</sub>. We'll discuss the sources of these ad nauseam in this class, so I won't spend any time on those here.

10. How much exchange is there between the various levels of atmosphere?

This is a great question! I'm not sure there is a clear answer. The most important exchange we'll consider is that between the stratosphere and troposphere. It's thought that about 1/3 or 1/2 of the ozone in the troposphere is due to exchange with the stratosphere. But the definition of "how much air is exchanged between different levels" is really a question of time scales. If you are talking 100s to 1000s of years, most of the air is exchanged between all levels. If you are talking 1 year or less, there could be very little exchange on that timescale.

11. Chapter 1 of the text describes the phase rule: "the number  $n$  of independent variables determining the equilibrium of  $c$  chemical components between a number  $p$  of different phases is given by  $n = c + 2 - p$ ." Temperature and mole fraction are examples of independent variables in the text. How are these variables determined? Are they the same variables no matter the system being described?

Sorry Aaron, I'll have to think about this one a bit before trying to answer coherently!

12. Chapter 4 of the text describes the subsidence inversions that define the planetary boundary layer. Why do these inversions happen so consistently at 1-2 km above the surface? Wouldn't the height of the subsidence inversion vary depending on the height of the cloud formation that is the source of the air?

I guess it is probably due to the amount of heating that one can expect over land during the day, and the typical lapse rate of the atmosphere. But another good question that I will need to research in order to answer!

13. In Chapter 2, the text mentions that  $H$  is a convenient measure because pressure and density decrease by a factor of "e" with each increase in  $H$ . This seems arbitrary. Is there a reason for this beyond picking the natural logarithmic factor?

Not that I am aware of. It's probably no more (or less) arbitrary that calling the decay time of a radioactive material to  $\frac{1}{2}$  of the original value the "half life." It is probably just a convenience more than anything else.

14. Does atmospheric stability always refer to the tendency for air to return to its initial vertical position or is this just one type?

As far as I know, it's simply a term to describe whether or not the atmosphere is susceptible to overturning by convection. A stable atmosphere won't turnover (unless there is some other forcing, like a strong wind with turbulence), whereas an unstable atmosphere won't last very long in that state.

- 14b. (not a question) The section on turbulent vs advective flux was dense, and it might be helpful to have a quick walkthrough if this is an important concept.

Yup, I agree completely!

15. Why is the least humid part of our atmosphere above the South pole (as opposed to the North pole or the desert)?

As far as I know, it takes physical removal (i.e., sedimentation of ice) to remove  $H_2O$  vapor to levels as low as what are observed over the Antarctic (or other cold places). A desert is dry partly because it is hot, and water is removed from the soil. Antarctica isn't dry. It's a big ice sheet, after all. It's just really really cold! So when that air is cold, the water condenses and falls out. Unless there is way to re-humidify that air, it will retain that very low humidity. I hope this is a decent answer to your question!

16. Does that mean that cooling is the most efficient way to remove moisture from air?

I think so!

17. Then it is ironic that dry deserts are typically very hot?

Well, part of the reason the air is dry over the desert is that the air descending from above has been frozen and dried out by ascent in the tropics. That's probably what's ironic, I suppose.

18. Why do I need to submit a file along with these text questions?

Trying to fix that! Stay tuned!

19. From the ideal gas law,  $PV=nRT$  or  $V=nR(T/P)$ , it is clear that at constant temperature and pressure, volume and molecules are directly proportional. Are Vol% and Mol% the same?

Wow – great question! In fact, there is a slight difference between volume fraction and mole fraction. This has to do with the finite volume occupied by molecules (and intermolecular forces).

20. In figure 4-24 in Jacob, it is indicated that it takes 5-10 years for air to be transported from the surface to the stratosphere but that it takes only 1-2 years for air to be transported back down from the stratosphere to the troposphere. It only takes approximately 1 month for air to be transported from the surface to the top of the troposphere. How is the stratosphere not losing air to the troposphere?

So I think you are referring to the notion that the timescale to mix air upward is different from the timescale to return it back down (right?). I think the reason these time scales are different has to do with the size of the “spheres” and the exchange time (which much be the same, up and down). If there is 5 times as much mass in the troposphere than the stratosphere, it will simply take 5 times as long for the air to be exchanged, if the mass exchange rate is “so many kgs per year”. The time it takes is the mass divided by the exchange time. Does this help?

21. Over-arching question: Will we be discussing stable isotopes of water (precipitation) in this course; is the course geared towards pollutants?

Definitely a course geared toward chemical transformation (in which case pollution is a key element of that) more so that geochemical and hydrological cycling). But I'll try to fit in some of this, if I can.

22. Clarifying question: Is the purpose of the discussion piece at the end of each problem to cement the steps taken to find an answer in your mind? Should this be a couple sentences? Do we need to submit the discussion with our original work prior to class or return to it afterwards?

As I noted in class, a way to put something down that will help you remember why it's important. More for you than for me.

23. On page 18 and earlier in the text it's stated that below 100 km (turbopause) the atmosphere is well mixed, (in comparison to the diffusion stratified region above 100 km), but what about the stratosphere where the air is stratified due to the temperature increase with altitude, and where turbulent mixing therefore does not occur as in the troposphere? Doesn't any diffusion stratification occur in this region?

Believe it or not, the stratosphere is pretty well mixed for long-lived gases like  $N_2$  and  $O_2$ . It's less well-mixed in terms of compounds that are highly reactive, of course. But that's just because timescales for mixing are on the order of “years”, so that gradients take that long to eliminate. So there isn't much diffusion to worry about in the stratosphere. Mainly above 60-80 km we start to worry about stratification of long-lived species due to differences in molecular weights.

24. How is ozone ( $O_3$ ) so effective at filtering / absorbing UV radiation, at only 0.01 to 10 ppm in the stratosphere? Is the ozone layer simply thick enough that any UV radiation passing through

it is going to encounter an ozone molecule at some point on its path through the ozone layer, despite the relatively low density of  $O_3$ ?

We'll talk about this. We can use Beer's Law to figure out how effective the absorption of UV light is for a given amount of ozone.

25. How does the density/makeup of the entire atmosphere compare to that of the troposphere?

Not too different, until you get up above 100 km.

26. What is the life span of atmospheric  $CO_2$  compared to other greenhouse gasses?

Hundreds to 1000 of years. But this is a tricky thing to show. Maybe I'll get into it. Remind me if I don't.

27. Why are you writing density in the  $PV=nRT$  equation? Is it molar density? I thought "n" was moles, but maybe I am confused.

Well, this is really just being sloppy. "N" (being capitalized) usually means that we are talking about a quantity that is an "extensive" variable. The amount increases with volume (or "extent" or size) of the system. I can define N to be whatever I want – total number, number of moles, etc. "n" (being little "n") means number density or number concentration, which we also call "[M]."  $N/V = n$  or [M]. Usually, atmospheric people use rho ( $\rho$ ) for mass density.

28. So, to make sure: What is the main difference between n, N and M in this equation that you wrote on the white board? I think I got a little bit confused on Thursday.

See above. Sorry for rushing through. They are all pretty much the same equation, as long as you recognize that you need to get "R" in the right units. The only other true variables of concern are T and P.

29. Scale height: if scale height depends on T ( $H=RT/Mg$ ), and T changes with altitude z, then how much does this variability in H influence the P(z) curve?

Woo hoo! See Problem 11.

30. How did we first measure the T(z) curve? First publications and dates?

I have no idea! Let's see what we can dig up!

31. How do the prevailing winds today compare to the prevailing winds during the era of Pangea? i.e. Do near-surface friction forces play a significant role in prevailing atmospheric transport?

I'm guessing that on a local scale, it mattered a lot. Surface roughness reduces wind speeds a lot in the lowermost few meters of the atmosphere. But on a planetary scale, I'm guessing the differences weren't that significant. But it would be interesting to explore!

32. Could you talk in some detail about the material in the turbulence section? It's a bit overwhelming at first glance.

Hmm. Let me see what I can do when we really need it. It's pretty thick stuff.

33. Can you go over, in more detail, exercise 1-3 on page nine?

Hmm. Let me think about this. It's not really something we need to get too deep into. Maybe better to ignore?!

34. Can you explain the standard reaction rate expression and the relationship to number density and collision frequency?

Yes – we'll get to that very soon!

35. In exercise 1.3 solution, they discuss how aerosol uptake of water at high humidities reduce visibility and produce a haze. Can you explain more how this phenomenon happen?

Yes, we'll get into this soon. It's a process called deliquescence.

36. The book discuss how the formation of clouds takes place when  $P_{\text{H}_2\text{O}} \geq P_{\text{H}_2\text{O,SAT}}$ . Does altitude affect the clouds formation? When know that the pressure decreases as you go from sea level to mountains.

Yes, insofar as air rising in altitude cools, so this drives condensation.