Chemistry 500: Chemistry in Modern Living

Topic 1: The Air We Breathe

States of Matter, Reactions, and Risk

Chemistry in Context, 2nd Edition: Chapter 1, Pages 1-34

Chemistry in Context, 3rd Edition: Chapter 1, Pages 1-44

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1A What is Air?

- Views about Air in history

- Ask Students: What are some evidence that air has substance?
    - Group Activity
    -
    -
    -

- Ask Students to Estimate Breathe Volume
  - Group Activity
  - Estimate the daily volume of air you breathe
    - An example of estimation

- What is "accuracy" and "precision"
  - Accuracy tells you how close your answer is to the "true value"
  - Precision tell you how much "variability" is in your answer
  - Upper and lower bounds
  - Outliers
    - Causes include real variability, measurement error and calculation error, and random error

- Role of Experiment
  - Individual educated guess
  - Group educated guess
  - Rough Experiment
  - Better Experiment
  - Precise Experiment

1B The Major Components of Air

- Graphics from Text: Figure 1.1, the Composition of Air

- Nitrogen
  - The "inert" component of air
  - N_2 very seldom involved in chemical reactions
  - Few organisms can react N_2
  - Very difficult for earliest chemists to find
  - ≈ 78% of air
  - Used industrially to "blanket" air sensitive processes such as steal making
  - Liquefies at -196 °C, 77 K

- Oxygen
  - The "reactive" component of air
  - O_2 involved in MANY chemical reactions, highly reactive
    - Oxygen "oxidizes" other chemicals (steals their electrons)
  - All organisms react O_2
    - Some require it, aerobic organisms
    - Some killed by it, anaerobic organisms
    - Always toxic unless the organism has the "tools" to detoxify it
  - ≈ 21% of air
  - Used industrially to "oxidize" materials in welding, chemical synthesis, etc.
  - Liquefies at - 183 °C, 90 K

- Ask Students: When would these percentages vary?
  - Group Activity
  -
  -
  -

- Ask Students: What happens when the O_2 content increases?
  - Group Activity
  -
  -
  -

- Ask Students: What happens when the O_2 content decreases?
  - Group Activity
  -
  -

1C The 1% Left Over in "Dry" Air

- Argon
  - Another "inert" component of air
  - Aralmost never involved in chemical reactions
  - No organisms can react Ar
  - ≈ 0.9% of air

- Carbon Dioxide
  - Another "reactive" component of air
  - CO_2 involved in many chemical reactions
  - Almost all organisms can react CO_2
  - ≈ 0.035% of air we breathe in
  - ≈4% of air we breathe out
  - Toxic in high concentrations, used in fire extinguishers
  - "dry ice" sublimes at -78 °C

- Water
  - Another "reactive" component of air
  - H_2O involved in MANY chemical reactions
  - All organisms can react H_2O
    - In fact: they exist in a sea of H_2O and it is involved in all biochemical processes either directly or indirectly
  - ≈ 0-4 % of air we breathe in (depends on humidity)
  - ≈4% of air we breathe out
  - Melts at 0 °C (273 K), 32 °F
  - Boils at 100 °C (373K), 212 °F

1D Measuring Small Quantities

- Percentage, %
  - 1 % = 1/100
  - Mellon
- Parts Per Million, PPM
  - 1 PPM = 1/1,000,000
  - Grape
- Parts Per Billion, PPB
  - 1 PPB = 1/1,000,000,000
  - Sugar grain
- Parts Per Trillion, PPT
  - 1 PPT = 1/1,000,000,000,000
  - Speck of dust

1E Scientific Notation

- Used to express very large numbers or very small numbers in a compact form
  - This saves space in writing and time in talking
  - 602,300,000,000,000,000,000,000 = 6.023×10^{23} (mole)
  - 0.000,000,000,1 = 1×10^{-10} (atomic distances in meters)

- How to Express Scientific Notation
  - First number x $10^{\text{second number}}$
  - The first number is used to "fine tune" the value
  - The second number is used to give the "size" of the value
    - "Order of magnitude"
    - Tells you how far to shift the decimal point and in what direction

- Examples
  - $3 \times 10^{4} = 30{,}000$
  - $5 \times 10^{7} = 50{,}000{,}000$
  - $3 \times 10^{-4} = 0.000{,}3$
  - $5 \times 10^{-7} = 0.000{,}000{,}5$
  - $3.02 \times 10^{4} = 30{,}200$
  - $5.26 \times 10^{7} = 52{,}600{,}000$
  - $3.02 \times 10^{-4} = 0.000{,}302$
  - $5.26 \times 10^{-7} = 0.000{,}000{,}526$

- Ask Students: Express each of the following numbers as conventional numbers or scientific notation, as required.
  - Group Activity

  - 2.68×10^{3}
  - 2,680,000
  - 2.68×10^{-3}
  - 0.000,000,268

- This is a convenient way to express Significant Figures
  - A measure of the Precision of a measurement (i.e., the number of reliable figures)
  - The number of significant figures of the answer can't be higher than the number of significant figures of any of the data put into the problem
  - The first number in the scientific notation tells us the number of significant figures
    - 3×10^{4} = 30,000 has 1 significant figure
    - 3×10^{-4} = 0.000,3 has 1 significant figure
    - 3.02×10^{4} = 30,200 has 3 significant figure
    - 3.0256×10^{-4} = 0.000,302,56 has 5 significant figure

- Ask Students: Give the number of significant figures.

  - Group Activity

  - 2.68×10^{3}
  - 2,680,000
  - 2.68×10^{-3}
  - 0.000,000,268

- Ask Students to calculate the mileage (mpg) of a car that travels 173 miles on 12 gallons of gas
  - Group Activity
  - Ask students to discuss what the number of significant figures should be
  - 173/12 = 14.416666…???
  - 173/11 = 15.727273…
  - 173/13 = 13.307692…

1F The Minor Components of Air (Major Pollutants)

- Four Main Gasses fall into this category
  - Carbon Monoxide, CO
    - 4-10 ppm
    - Poison via its interaction with hemoglobin
  - Ozone, O_3
    - up to 0.2 ppm (200 ppb)
    - very irritating to mucous membranes

- Sulfur Oxides, SO_x
  - $SO_x = SO_2$ and SO_3
  - Mixture up to 0.3 ppm (30 ppb)
  - from combustion of fossil fuels rich in sulfur

- Nitrogen Oxides, NO_x
  - $NO_x = NO$ and NO_2 and others, Mixture
  - up to 0.05 ppm (50 ppb)
  - from high temperature combustion reactions

- Ask Students: Which cities have pollution about the federally mandated pollution limits
  - Group Activity
  - Graphics from Text: Table 1.2, Pollution Levels for Major US Cities
    -
    -
    -

- Ask Students: What factors contribute to some cities having particularly high levels of pollution or particularly low levels of pollution?
  - Group Activity
    -
    -
    -

1G Risk Assessment

- The Key Variables/Questions that must be considered when evaluating the risk of an activity, item, etc.
  - Exposure
    - Was the individual exposed to an Average Dose or an Extreme Dose
    - Was it a Chronic Exposure or was it an Acute Exposure
    - The relative importance of these variables is due to the individual mechanism of chemical and biological interactions
      - Dose - Response Curves: Toxicity at micro doses vs. harmless below some critical dose

- Toxicity and its Evaluation
  - Efficacy and Ethics both come into play
  - Each method has strengths and weaknesses
    - Studies on Individual People
    - Human Population Studies
    - Natural Controlled Experiments
    - Animal Studies
    - Microorganisms
    - Tissues
    - Computer Models

- Risk ≈ Exposure x Toxicity
  - Multiple combinations of variables
    - Average Exposure x Chronic Exposure
    - Average Exposure x Acute Exposure
    - Extreme Exposure x Chronic Exposure
    - Extreme Exposure x Acute Exposure

- Value Judgements
  - The numbers for Risk can be calculated with reasonable precision
    - Differences between experts due to differences in input data and differences in the model used
  - The meaning of the numbers (i.e., is the risk acceptable or is the risk to bad) can only be based on individual values and community values

1H Breath

- Inhaled Air and Exhaled Air
  - Graphics from Text: Table 1.1, Inhaled and Exhaled Air
- What happens in metabolism? (Fire!)
  - O_2 consumed
  - CO_2 and H_2O exhaled

Gas	Inhaled %	Exhaled %
N_2	78%	75%
Ar	0.9%	0.9%
O_2	21%	16%
CO_2	0.03%	4%
H_2O	0-4%	4%

- Ask Students: Why does each gas go up or down?
  - Group Activity

1I States of Matter

- States of Matter are Defined by Physical Properties
  - Physical Properties
    - Dimensional Stability
    - Flow Up vs. Flow Down
    - Density
  - States of Matter
    - Solid
    - Liquid
    - Gas
- Reactions of Matter are Defined Primarily by Chemical Properties
  - No fundamental change in reactivity when the state changes
  - The rates of reactions may change

1J Air Pressure and the Atmosphere

- Graphics from Text: Figure 1.2

- Regions of the Atmosphere
  - Mesosphere
    - Above about 30 miles / 50 Km
  - Stratosphere
    - Above Passenger Jets
    - Contains "Ozone Layer"
  - Troposphere
    - Where we live, below about 10 miles / 17 Km
    - Contains the "Biosphere" and the "Geosphere"

- Atmospheric Pressure
  - 14.7 psi (pounds per square inch)
  - 1 atmosphere
  - Graphics from Text: Figure 1.2 (and 1.3 in 3rd Edition)
  - Pressure Gradient
    - Caused by a Balance of Forces
      - Molecular Motion causes molecules to want to fly free
      - Gravity causes the molecules to be attracted to the surface

1K Elements, Compounds, and Mixtures

- Element
  - Purity and Indivisibility

- Compound
  - Purity and Indivisibility

- Mixture
  - Purity and Indivisibility

- Ask Students: Identify five each of Elements, Compounds, and Mixtures found in your home
  - Group Activity

1L Atoms, Molecules, and Formulae

- The Interaction of Theory and Experiment

- How do we know:
  - The structure and size of Atoms
    - Diffraction
    - Elegant "wet experiments"
      - E.g., surface films
  - The formulae
    - Definite ratio of elements
    - Elemental Analysis
  - The structure and size of molecules
    - Diffraction of X-rays
    - Sporting Methods based on electromagnetic radiation

1M What is a Mole?

- A small furry creature that looks like a mouse without a tail

- A number (like a dozen)
  - 602,300,000,000,000,000,000,000
  - 6.023×10^{23}
  - Avogadro's Number
  - Relates the number of atoms to macroscopic scales (i.e., atomic mass units, AMU, to grams)

- Examples of the size of a mole
  - Air you breathe
    - One litter of air contains 2.69×10^{22} molecules
    - One breath of air contains $\approx 10^{22}$ molecules
    - Considering the total volume of air in the atmosphere
    - Each breath contains about 6×10^{8} molecules previously breathed by any historical figure

- Marshmallows
  - One Avogadro of marshmallows would cover the US 650 miles thick
- Money
  - One Avogadro of dollars given to the world would let each person spend one million dollars per hour till they die without using all of the money up

1N Reactions and Equations

- An Equation is a Chemical Sentence
  - It tells you the relative proportions of the different reactants and products

Reactants → Products

- One of the main skills in Chemistry is to be able to balance a chemical reaction
  - The key steps in this are that **YOU ARE NOT ALLOWED TO CHANGE THE FORMULAE OF MOLECULES and that YOU CHECK YOUR WORK**

$$\_\_\_\ Na + \_\_\_\ Cl_2 \rightarrow \_\_\_\ NaCl$$

$$\_\_\_\ CO + \_\_\_\ O_2 \rightarrow \_\_\_\ CO_2$$

$$\_\_\_\ H_2 + \_\_\_\ O2 \rightarrow \_\_\_\ H_2O$$

- Ask Students: Balance each of the following reactions.

  - Group Activity

$$\_\_\_ \ O_3 \rightarrow \_\_\_ \ O_2$$

$$\_\_\_ \ C + \_\_\_ \ O_2 \rightarrow \_\_\_ \ CO_2$$

$$\_\_\_ \ CaO + \_\_\_ \ HCl \rightarrow \_\_\_ \ CaCl_2 + H_2O$$

$$\_\_\_ \ CH_4 + \_\_\_ \ Br_2 \rightarrow \_\_\_ \ CH_2Br_2 + \_\_\_ \ HBr$$

$$\_\_\_ \ C_2H_6 + \_\_\_ \ O_2 \rightarrow \_\_\_ \ CO_2 + H_2O$$

$$\_\_\_ \ H_2SO_4 + \_\_\_ \ NaOH \rightarrow \_\_\_ \ Na_2SO_4 + \_\_\_ \ H_2O$$

1O Fire and Fuel

- Hydrocarbons
  - Molecules composed only of Carbon and Hydrogen

- Natural Gas
  - Methane, CH_4, major component
  - Hydrogen Sulfide, H_2S, added because of its smell
    - Toxic at higher concentrations
  - C2, C3, and C4 alkanes now removed for plastics manufacture

$$CH_4 + 2O_2 \rightarrow CO_2 + 2\ H_20 + \text{Heat}$$

$$C_8H_{18}\ (\text{Octane}) + 12.5\ O_2 \rightarrow 8\ CO_2 + 9\ H_20 + \text{Heat}$$

- What happens if one uses an excess of O_2
  - What happens if one uses a shortage of O_2

1P Air Quality

- Graphics from Text: Figure 1.6 and Table 1.7 in 2nd Edition and Figure 1.7 and Table 1.7 in 3rd Edition: Changes in the average air pollution in the US since 1970

- Ask Students: Answer the following questions.
  - Group Activity
  - Why hasn't NO_x gone down?
  - Why has SOx dropped so much?

- Why did Lead, Pb, drop?

- Why is CO lower?

- Why have VOCs (Volatile Organic Compounds) dropped?

- Why have PM-10 (Particulate Matter - 10 μ) dropped?

1Q Deadly Air Pollution, Deadly Fog

- 1952 London England, 4,000 Deaths
- 1948 Donora PA, 20 Deaths
- Why was pollution so acutely toxic in these times and places?
  - Aerosols (liquid whose drops are so small they float) breathed into lungs
  - Metals in ash particulates catalyze the conversion of SO_2 to SO_3

$$SO_2 + 1/2\ SO_3 \rightarrow SO_3$$

$$SO_3 + H_20 \rightarrow H_2SO_4$$

1R Photochemical Smog

- Heat in car engines, etc., leads to NO_x formation
- NO_x reacts with VOC to produce O_3
- Ozone is one of the most irritating components of smog
  - Can be fought by lowering NO_x and/or VOC

$$N_2 + O_2 \rightarrow 2\,NO$$

$$NO + 1/2\,O_2 \rightarrow NO_2$$

$$NO_x + \text{Hydrocarbons} + \text{sunlight} \rightarrow O_3$$

Problems: xxx

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