Optimizing the Chemistry curriculum, its delivery, and its assessment in a degree in Health Sciences.

https://z.umn.edu/ChemAtUMR

Health Science Teachers Workshop
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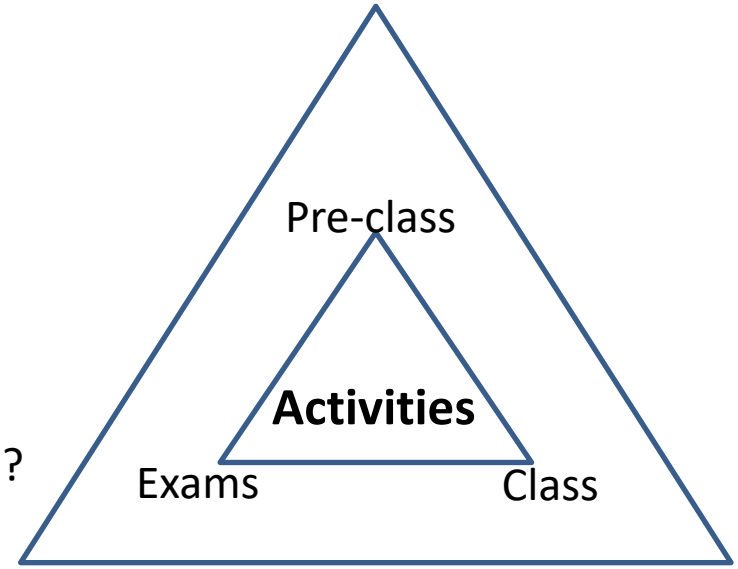
Curriculum design involves three intertwined tasks

What to teach?
(Content + skills + attitudes = Curriculum)



What students learn?
(Assessment)

How to teach it?
(Pedagogy)

→ We want to align “what we transfer to students” (content) with “what students do” (in class) with how students are assessed (what the exam looks like)

What to teach: Taxonomy of Chemistry Topics

Table 1. Comparison of "Big Ideas" over the Last 20 Years

Gillespie[147]	Atkins[148]	AP Chemistry Big Ideas[149]	ACS General Chemistry Curriculum Map Anchoring Concepts[150,151]	CLUE Core Ideas[152]
(1) atoms, molecules, and ions	(1) matter is composed of atoms	(1) atoms	(1) atoms	(1) atomic/molecular structure and properties
(2) the chemical bond	(2) elements form families	(2) chemical and physical properties	(2) bonding	(2) electrostatic and bonding interactions
(3) molecular shape and geometry	(3) bonds form by sharing electron pairs	(3) reactions: rearrangement of atoms and electrons	(3) structure/function	(3) energy
(4) kinetic theory chemical reaction	(4) shape is of the utmost importance	(4) rates/kinetics	(4) intermolecular forces	(4) change and stability in chemical systems
(5) energy and entropy	(5) molecules interact with one another	(5) thermodynamics/energy	(5) chemical reactions	
	(6) energy is conserved	(6) bonds and interactions	(6) energy and thermodynamics	
	(7) energy and matter tend to disperse		(7) kinetics	
	(8) there are barriers to reaction		(8) equilibrium	
	(9) there are only four fundamental types of reaction		(9) measurement and data	
			(10) visualization and scale	

Source: Cooper and Stowe https://pubs.acs.org/doi/10.1021/acs.chemrev.8b00020

→ Do you have the flexibility of teach whatever you want?

→ A health science course with chemistry or a chemistry course with health science?

Points of integration of Chemistry in Health and Environmental Science

https://docs.google.com/document/d/1Sx9DnDdUOmFN1GpFP4WACj5tbd3aFBWPXGvhCLDztSY/edit?usp=sharing

What to teach: Taxonomies of skills (actions)

PRACTICES FOR K-12 SCIENCE CLASSROOMS

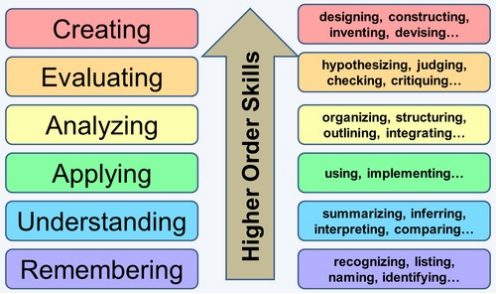
1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

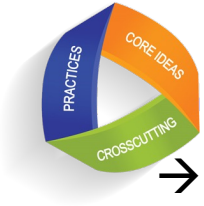
Source:
https://www.nap.edu/read/13165/chapter/7#42

Uri Zoller et al

Higher-Order Cognitive Skills
vs
Lower-Order Cognitive Skills

Bloom's or Marzano's Taxonomy

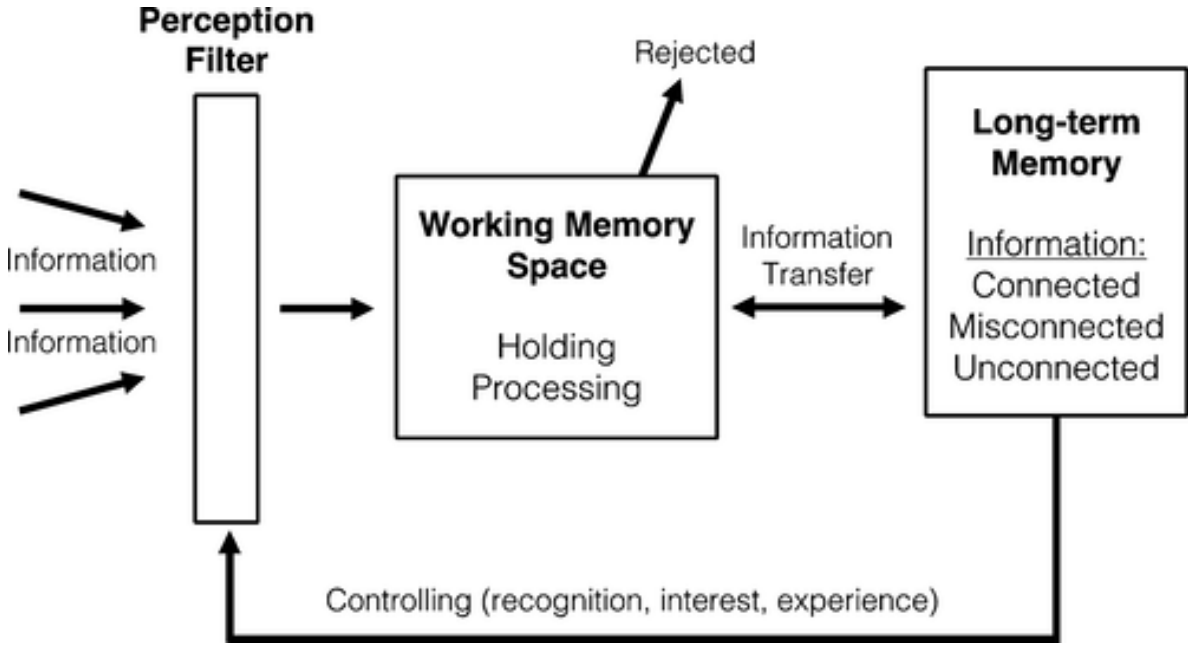




→ Typically a HOCS will be required with questions such as explain with words, or drawings. Rarely it will be algorithmically, and therefore, rarely can be coded into multiple choice.

→ Open-ended or data-driven, while not necessary, they'll typically guarantee a HOCS exercise.
The problem is that open-ended and data-driven are harder to grade and therefore, students may not get the **prompt and clear** feedback.

Assessment: How do novices learn new content and skills?



The process of chunking is wrapping several concepts into simpler ones so that one lowers the cognitive load and leaves room for processing.

Adding context will work as glue to keep the chunks together. But it is actually ”practice and fast feedback” that will allow students to glue the chunks.

Novices

Have high cognitive load
Do not see connections
Require Type II thinking (they have to think about it to see it)

Experts

Connect the topics
Identify meaningful patterns of information
Have chunked the information to lower cognitive load
Chemical intuition: Type I thinking
Capable of High Order Cognitive Skills (HOCS)

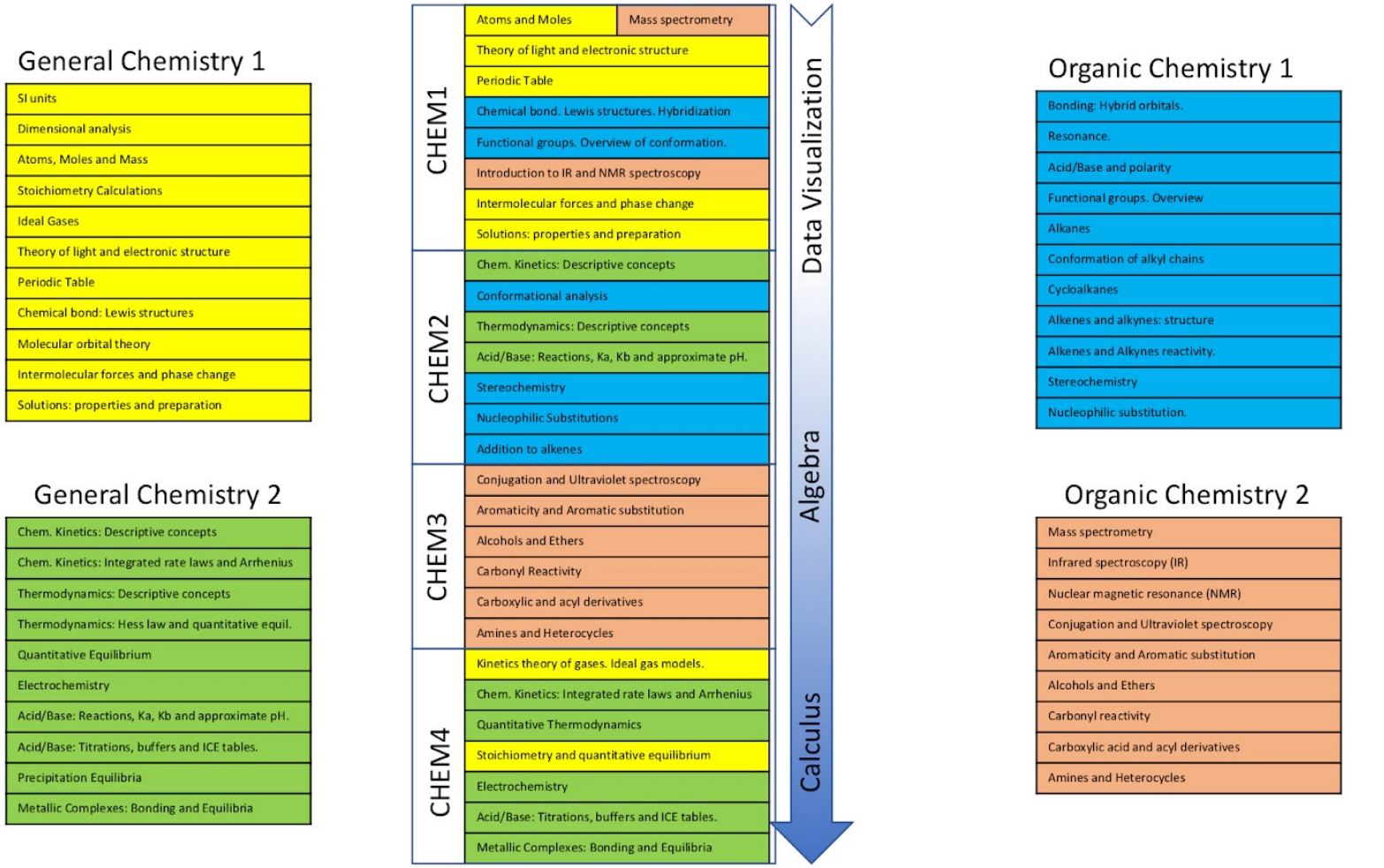
Option 1: Health science, but not really.
Substance X is a drug used for treating Y.
Calculate how many grams of X you need to give to prepare a solution of 0.2 mM.

Option 2: Realistic health science problem.
Substance X is a drug used for treating Y.
Calculate the dose a patient needs for a sustained effect of 48 hours.
Before any calculations, the student needs to understand the problem and find out: Desired blood concentration, volume of blood, time of drug activation and decay…

Problem: Introducing a context such as Health Sciences will increase the students cognitive load.

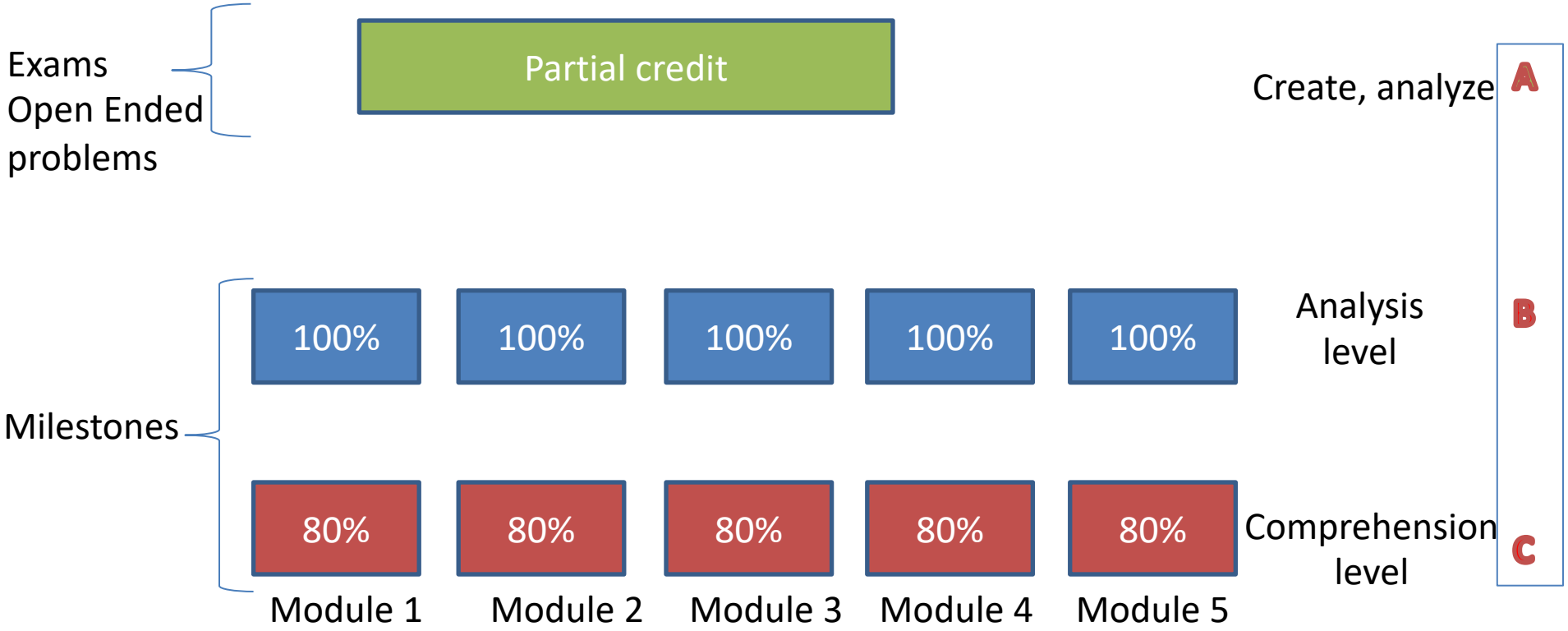
What we do at UMR for content: Resequencing the GC/OC courses

https://sites.google.com/r.umn.edu/chemistry-at-umr



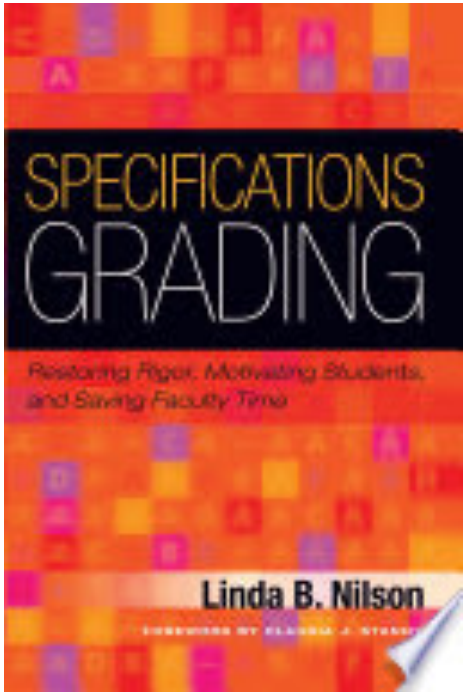
→ Organic/Bioorganic compounds are introduced since the very beginning. Integration.
→ Experimental evidence is used everywhere (NMR, IR during first semester)
→ Math is progressively introduced. Draw, Explain, Represent before Calculation

What we do at UMR for assessment: 2 types of exams. Milestones



→ The milestone exams are aimed at helping students reach the required level of LOCS necessary to tackle HOCS.
→ They need to be proficient in order to make the connections.
→ They are graded on A/C/F scale: no partial credit
→ They have access to the pool of questions ahead of time so they can practice
→ The milestone exam is taken on the computer, during proctored outside of class time.
→ They have 3(?) attempts to achieve the goal.
→ The questions are cumulative so that they are stored in long-term memory

What we do at UMR for assessment: Milestones



Makes it very clear what the objective of the course is, and therefore the meaning of each letter grade.
Exercises are graded by either getting all the points or none.
Each exercise is linked to a learning objective

Examples:

- Number of p+, n0 and e- in 13C+
- Rank x-rays, microwaves, red light and blue light by decrease energy and by decreasing wavelength
- Write the electronic configuration of Ca2+
- Draw the Lewis structure of CO2
- How many hydrogens and carbons does the molecule of cyclohexene contain?
- (…)

Actual Milestones: http://chem.r.umn.edu/chem1331/milestones/

What we do at UMR for delivery: regular class structure

Preclass materials

Videos: 1 per topic – 5:7 min – All finish with a retrieve/application question (LOCS)
The videos set the material, we are not bound by what we cover in class.

Terms to be added to the glossary

Pre-class: Follows the "DERC:draw, explain (following a glossary), represent, calculate"

Must bring on paper the pre-class questions

In-class structure

Semi-active learning: Combine 10 min lecture with 10 min activity.

Easy/recall: DERC Harder/problem solving/ exam-like: DERC

Nothing is graded in order to decrease the anxiety towards learning

Distribute the class activities on paper.

Assessment

Milestones: proctored – aiming at LOCS

Exams: context-rich, open ended DERC questions.

Practicing HOCS/Scientific practices – no LOCS asked.

What to do during class time?

Who does it?

1) Teacher
2) Individual student (not graded)
3) Individual student (graded)
4) Group of students (not graded)
5) Group of students (graded)

What do we do?

I. Explain topic to everyone
II. Solve problem to some
III. Teacher – Student – Q&A (all class)
IV. Teacher – Student – Q&A (walk around)
V. Work on short problem
VI. Work on long problem
VII. Student presentations
VIII. Quiz time

Positive

A) Engage students
B) Cover necessary material
C) Good challenge to students
D) Bring everyone on board
E) Practice several skills (outcomes)
F) Control pace of class (finish on time)
G) Clear feedback to students

Negative

a) Too much challenge
b) Too easy
c) Lose control of pace
d) Unclear objectives (frustration)
e) "Not in the exam"
f) Unclear feedback to students

Task: Prepare your perfect session.

a) Choose one problem from the Health Science problems list (ahead)
b) choose a form of activity from the previous page.
   Identify “Who”, ”What”, “Positives”, and “Negatives”
   a) You may decide a combination of forms of activity.
   b) Decide how long it would take for each form of activity.
   c) Think about how students should come prepared to class
   d) Think about what you are going to assess them on.
c) Is it a health science “context rich” or “context poor”?

Typical sequence of topics in chemistry

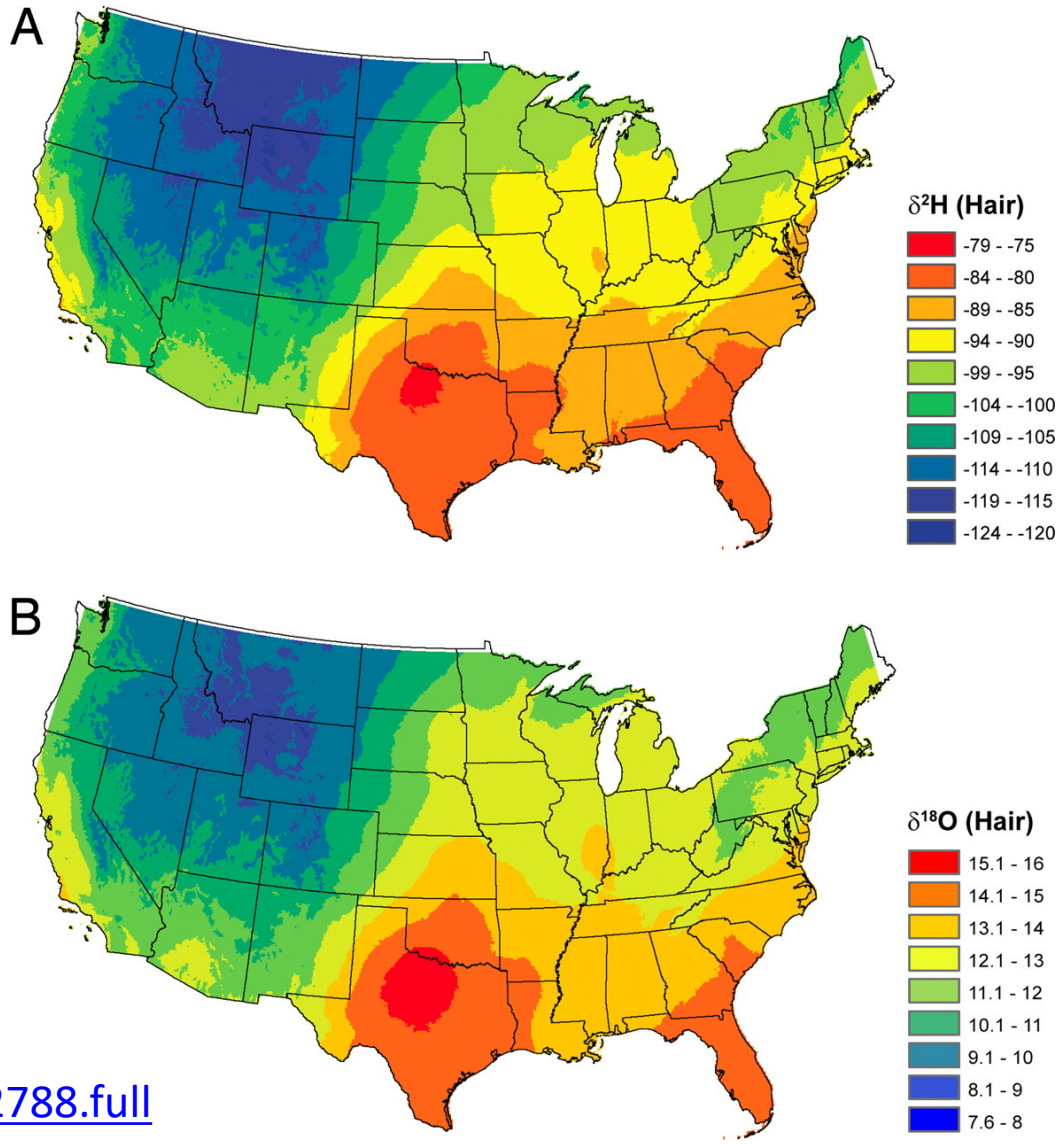
1. Atomic composition
2. Light and electronic structure
3. Bonding and molecular structure
4. Structure/Function - Phases and Phase change
5. Intermolecular forces, solutions and solubility
6. Chemical reactions: Stoichiometry and equilibrium.
7. Ionic equilibria: Acid/Base and precipitation
8. Kinetics
9. Thermodynamics
10. Electrochemistry

Applications of Isotopic signature (I): Oxygen and Hydrogen: The origin of water

Hydrogen and oxygen isotope ratios in human hair are related to geography

Water itself does not have the same H and O isotope distribution in different parts of the planet or the country.

Since the H and O of water will be absorbed by your body, just by analyzing your hair we can figure out where you have been.



http://www.pnas.org/content/105/8/2788.full

Applications of Isotopic signature (II)

Choose one article

Case 1:Water and US geography H,O

http://www.pnas.org/content/105/8/2788.full

Case 2: Carbon and nitrogen in your diet

http://onlinelibrary.wiley.com.ezp1.lib.umn.edu/doi/10.1002/rcm.4934/full

Case 3: Corn Fast food

http://www.pnas.org/content/105/46/17855.full

Questions:

- Write a brief description of the article
- The sample (hair, food) is usually turned into simpler molecules easier to analyze by the mass spectrometer. What are those?
- Describe how in your article scientist connect isotopic data with diet or geography
- How reliable is the method. Is the standard deviation small enough to distinguish between two different isotopic signatures?
- Do you think that the way the sample was collected may have influenced the final results?
- For case 3: After reading the critique and its reply (previous slide in “Controversy”). Who do you think is right?

Electromagnetic radiation and the Nocebo effect

1.Identify the areas of the electromagnetic spectrum that are harmful regardless of intensity
2.Identify the areas of the electromagnetic spectrum that are not harmful regardless of intensity

1. Search online for the meaning of the nocebo effect? What is it?
2. Why does the electromagnetic hypersensitivity contradict the photoelectric effect?
3. What is the World Health Organization position on Electromagnetic Hypersensitivity
http://www.who.int/peh-emf/publications/facts/fs296/en/

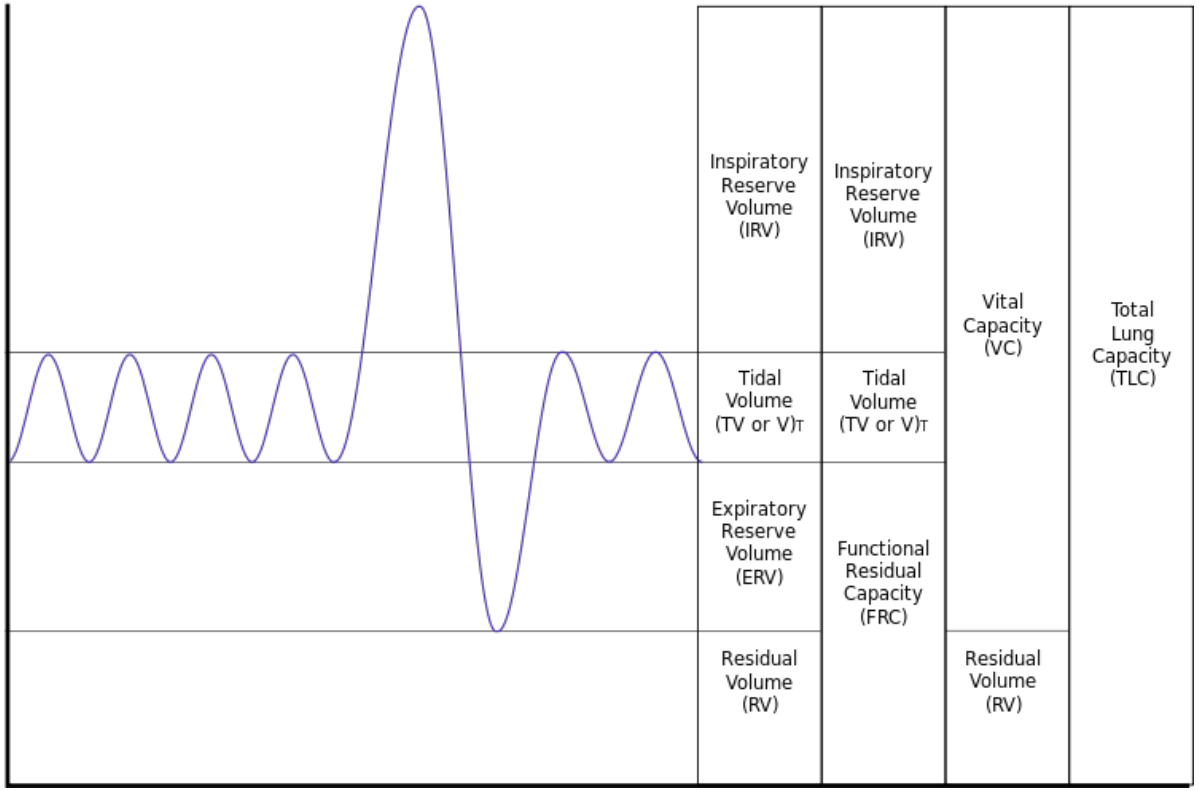
Units of concentration

A newborn needs to eat 150mL of milk a day for each kg that the baby weighs. So, if the baby weighs 2kg he/she will need to drink 300mL of milk. If your baby is 8 pounds 10 ounces and eats 8 times a day, how many mL of milk does he/she need to drink at every meal? What is the volume in ounces? And in cc?

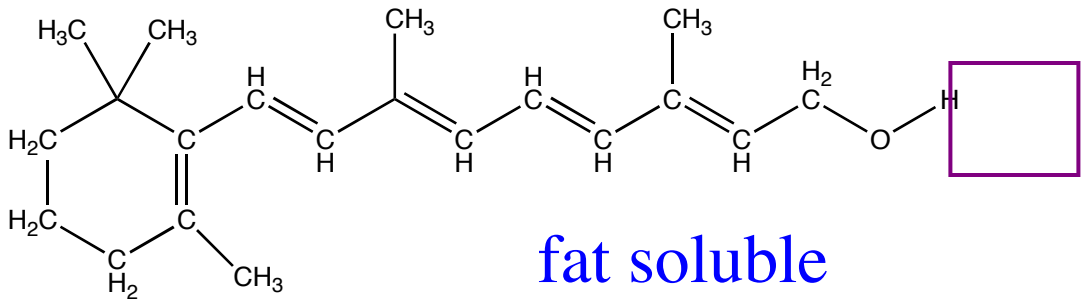
Gases – Application of Boyle's law

The tidal volume (volume of air moved into or out of the lungs during quiet breathing) is the same in women and in men (0.5L), however the initial and final volume is higher in men. Since the initial p= 1atm, calculate the final pressure in the men's and women's lungs when they inhale the tidal volume of air? Is this realistic?

Men (Liters)	Women (Liters)
3	1.9
0.5	0.5
1.1	0.7
1.2	1.1



Identifying polar bonds in vitamins. Which one is soluble in water?

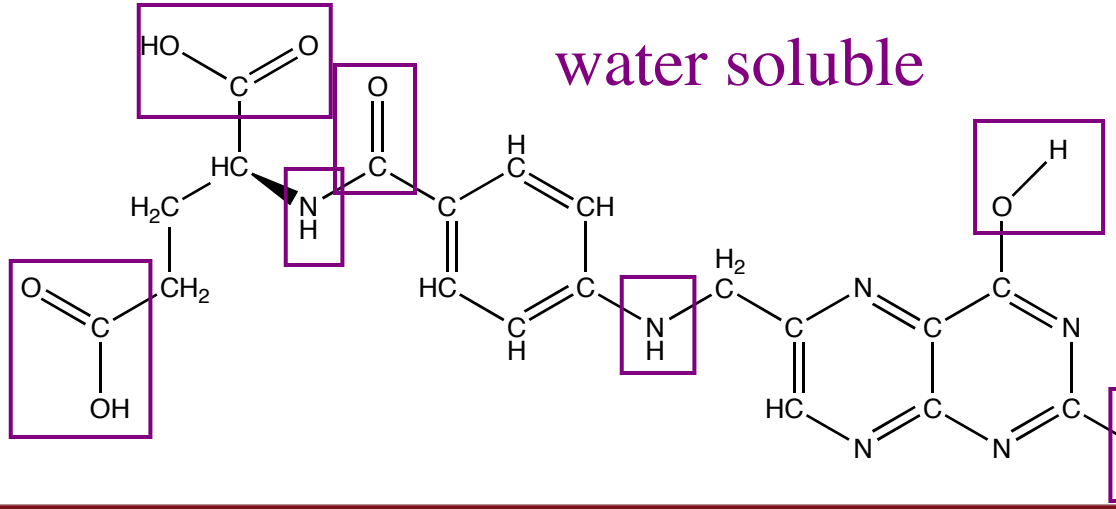


vitamin A

fat soluble

Which one will be easier to excrete by the bloodstream and kidneys?

water soluble



vitamin B9

(folic acid)

Vitamins and solubility (2)

Water soluble vitamins (ie. folic acid and vitamin C) are readily excreted.

Fat soluble vitamins (such as E and A) remain in the body much longer. Megadoses of fat-soluble vitamins have been shown to be harmful.

SUPPLEMENT FACTS

Serving Size: Two Tablets

(Amount Per Serving)	% Daily Value
vitamin A (25000 IU)	500%
Vitamin C (1000 mg)	1670%
Vitamin E (400 IU)	1300%
Zinc (50 mg)	333%
Copper (2 mg)	100%
Selenium (50 mcg)	71%
Chromium (200 mcg)	166%
Citrus Bioflavonoid Complex (250 mg)	
N-Acetyl L-Cysteine (200 mg)	*
Quercetin (100 mg)	*
Rutin (100 mg)	*
Bilberry Extract (80 mg)	*
Euphrasia officinalis (50 mg)	*
Alpha Lipoic Acid (50 mg)	*
Ginkgo Biloba (25 mg)	*
L-Glutathione (10 mg)	*
FloraGLO Lutein (6 mg)	*

* Daily Value not established

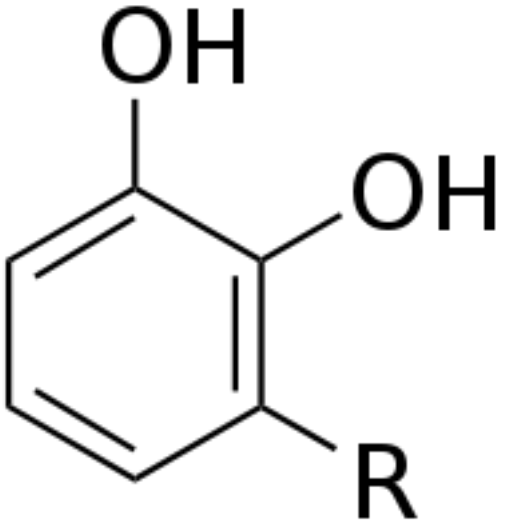
SUPPLEMENT FACTS

Serving Size: One tablet

Amount Per Servings	% Daily Value
vitamin A 2500 IU	50%
Vitamin C60 mg	100%
Vitamin D800 IU	200%
Vitamin E30 IU	100%
Vitamin K25 mcg	31%
Thiamin (B1)1.5 mg	100%
Riboflavin (B2)1.7 mg	100%
Niacin10 mg	50%
Vitamin B62 mg	100%
Folic Acid400 mcg	100%
Vitamin B126 mcg	100%
Biotin30 mcg	10%
Pantothenic Acid5 mg	50%
Calcium (elemental)450 mg	45%
Iron18 mg	100%
Magnesium50 mg	13%
Zinc15 mg	100%
Selenium20 mcg	29%
Copper2 mg	100%
Manganese2 mg	100%

Solubility and acid/base

Clicker: Treatment of poison of ivy rash: the components of poison ivy and poison oak that produce the characteristic itchy rash are catechols substituted by long aliphatic chains.



R = $(CH_2)_{14}CH_3$ or
R = $(CH_2)_7CH{=}CH(CH_2)_5CH_3$ or
R = $(CH_2)_7CH{=}CHCH_2CH{=}CH(CH_2)_2CH_3$ or
R = $(CH_2)_7CH{=}CHCH_2CH{=}CHCH{=}CHCH_3$ or
R = $(CH_2)_7CH{=}CHCH_2CH{=}CHCH_2CH{=}CH_2$ and others

If you were exposed to ivy, which of the treatment below would you apply to the affected area?

a) Wash the area with cold water
b) Wash the area with dilute vinegar or lemon juice
c) Wash the area with soap and water
d) Wash the area with soap, water and baking soda (sodium bicarbonate)

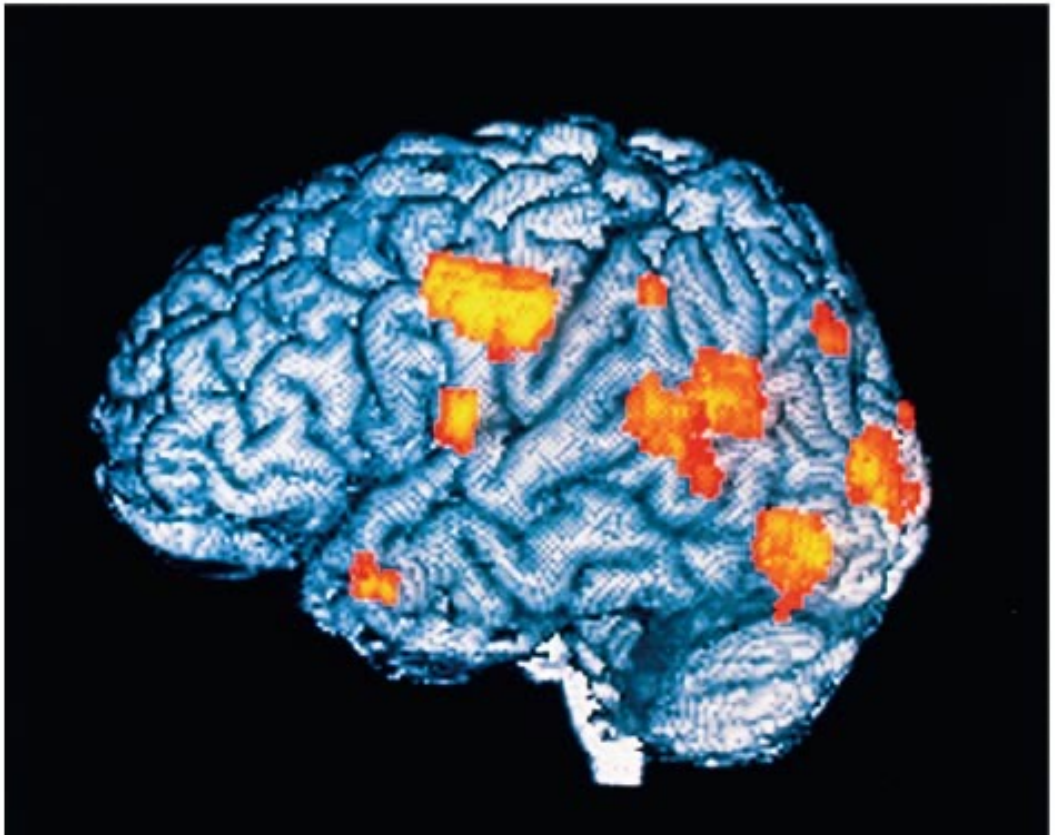
Kinetics and half-life

1. Insulin is a polypeptide hormone released from the pancreas that stimulates fat and muscle to take up glucose. In a certain patient, it has a first-order half-life in the blood of 3.5 min. To maintain an adequate blood concentration of insulin, it must be replenished in a time interval equal to 1/k. How long is the time interval in this patient?
2. Many drugs decompose in blood by a first-order process. Two tablets of aspirin supply of 0.60g of the active compound. After 30 min. this compound reaches a maximum concentration of 2 mg/100mL of blood. If the half-life for its breakdown is 90 min, what is the concentration (in mg/100mL) 2.5 hours after it reaches its maximum concentration?
3. For the decomposition of an antibiotic in a person of a normal temperature (98.6F), k = 3.1E-5 s-1; for a person with a fever at 101.9F, k=3.9E-5 s-1. If the person with a fever must take another pill when 2/3 of the first pill has decomposed, how many hours should the person wait to take a second pill? A third pill? (Assume the pill is effective immediately)

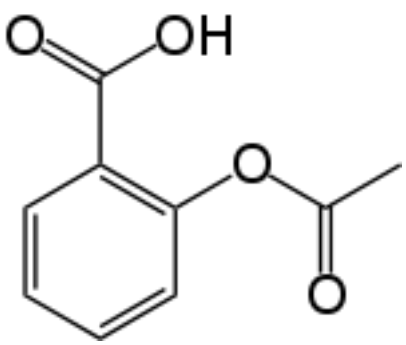
Radioactivity tracers

Fluorine-18 is a radiotracer that is used for brain scans. F-18 has a half-life of 1.83 hours. If 2.85 mg of F-18 is injected into a patient, what mass of F-18 is still present in 3.00 hours?

a) 1.74 mg
b) 0.113 mg
c) 0.950 mg
d) 2.53 mg
e) 0.914 mg



Acid/Base of aspirin



pH and Drug Absorption:
Aspirin is a weak acid with a pKa of 3.5

It is absorbed into the blood through the cells lining the stomach and the small intestine. Absorption requires passage through the plasma membrane, the rate of which is determined by the polarity of the molecule: charged and highly polar molecules pass slowly, whereas neutral hydrophobic ones pass rapidly. The pH of the stomach contents is about 1.5, and the pH of the contents of the small intestine is about 6. Is more aspirin absorbed into the bloodstream from the stomach or from the small intestine? Clearly justify your choice.

Buffers in blood: Acidosis and alkalosis.

The concentration of the buffer H_2CO_3/HCO_3^- in blood is:

$[H_2CO_3]=0.0012M$

$[HCO_3^-]=0.024M$

pKa=6.1

A 70kg person has a total blood volume of about 5.0 L. Given the carbonic acid and bicarbonate stated above, what volume (in mL) of 6.0 M HCl can be neutralized by blood without the blood pH dropping below 7.0 (which would result in death)?

pH and Drug Absorption

A pharmaceutical molecule with antifungal properties is only active when deprotonated and negatively charged (A-). The protonated state (HA) is inactive. If the pKa of this drug is 10.0.

a. Calculate the ratio of protonated to deprotonated compound at physiological pH (7.4).
b. Is this drug likely to be a useful pharmaceutical agent?

Absorption of aspirin (acetylsalicylic acid, C9H8O4,) into the bloodstream occurs only when the molecule is in its conjugate base form.

a. If a patient takes two tablets of aspirin (325 mg each), how many grams of aspirin are available for immediate absorption in the stomach? The pH of the stomach is 1.6, and the pKa of aspirin is 3.5.
b. Would you expect more or less aspirin to be absorbed in the small intestine (pH ≈ 7.5) compared to the stomach? Briefly explain your answer (no calculation is required).

Control of Blood pH by Respiration Rate:

a. The partial pressure of CO_2 in the lungs can be varied rapidly by the rate and depth of breathing.
   For example, a common remedy to alleviate hiccups is to increase the concentration of CO_2 in the lungs. This can be achieved by holding one's breath, by very slow and shallow breathing (hypoventilation), or by breathing in and out of a paper bag. Under such conditions, pCO_2 in the air space of the lungs rises above normal. Qualitatively explain the effect of these procedures on the blood pH.
b. A common practice of competitive short-distance runners is to breathe rapidly and deeply (hyperventilate) for about half a minute to remove CO_2 from their lungs just before the race begins. Blood pH may rise to 7.60. Explain why the blood pH increases.
c. During a short-distance run, the muscles produce a large amount of lactic acid ($CH_3CH(OH)COOH$, $K_a = 1.38E\text{-}4$) from their glucose stores. In view of this fact, why might hyperventilation before a dash be useful?

Calculation of Blood pH from CO2 and Bicarbonate Levels

Calculate the pH of a blood plasma sample with a total CO2 concentration of 26.9 mM and bicarbonate concentration of 25.6 mM. The relevant pKa of carbonic acid is 6.1.

Effect of Holding One's Breath on Blood pH

The pH of the extracellular fluid is buffered by the bicarbonate/carbonic acid system. Holding your breath can increase the concentration of CO2(g) in the blood. What effect might this have on the pH of the extracellular fluid? Explain by showing the relevant equilibrium equation(s) for this buffer system.

Buffers

1. A purified protein is in a Hepes (N-(2-hydroxyethyl)piperazine-N'-(2-ethanesulfonic acid)) buffer at pH 7 with 500 mM NaCl. A sample (1 mL) of the protein solution is placed in a tube made of dialysis membrane and dialyzed against 1 L of the same Hepes buffer with 0 mM NaCl. Small molecules and ions (such as Na+, Cl-, and Hepes) can diffuse across the dialysis membrane, but the protein cannot.
   a. Once the dialysis has come to equilibrium, what is the concentration of NaCl in the protein sample? Assume no volume changes occur in the sample during the dialysis.
   b. If the original 1 mL sample were dialyzed twice, successively, against 100 mL of the same Hepes buffer with 0 mM NaCl, what would be the final NaCl concentration in the sample?