Teaching using a Hybrid Course Model: Effective use of ALEKS to Engage and Prepare Students for Class

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"Getting students engaged and guiding their thinking in the **classroom is just the beginning** of true learning, however**.** This classroom experience has to be [supplemented] with extended "**effortful study**," where the student spends considerably more time than is possible in the classroom **developing expert-like thinking and skills.**"

– Carl Wieman

Outline

- Motivation for using a hybrid course model for general chemistry
- Description of the course model for engaging students
- Course assessment data to illustrate/define the need
- How ALEKS fits in to this hybrid model / course implementation

Incoming students struggle

Some students struggle in their first years in college because

- they don't know how to balance four classes
- they don't understand what we want from them
- they think that learning means showing up
- they hold on to major misconceptions about learning
- they lack some of the more fundamental skills from high school
- they need us to help them bridge the gap from high school to college

Students struggle to prepare for class

Students are unsuccessful at preparing for class because

- they don’t have a gauge for what is expected of them
- they "read", but like it's a story
- they "do problems", but rarely connect it to the course material
- they don’t seek help and are afraid to make mistakes
- they have a poor metacognitive sense

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Students are most able to succeed when

- they prepare for class
- they are given context for their work
- they are given explicit expectations (low or high)
- they are supported and given guidance
- they are challenged to find answers for themselves

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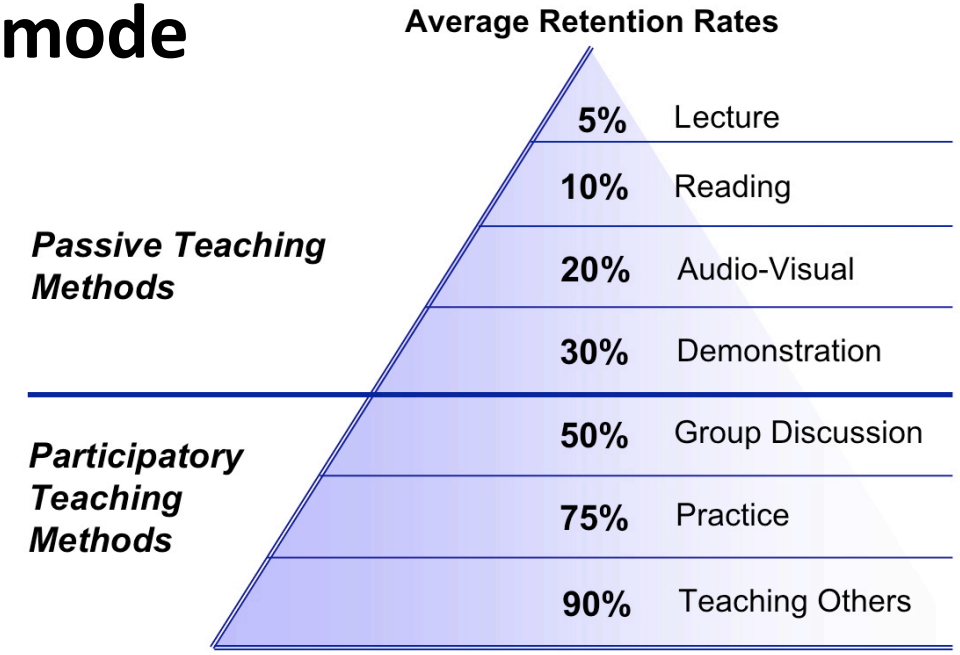
Our students crave the passive mode

- Students accustomed to working hard, but ineffectively
  - Highlighter
  - Flash cards
  - Rewriting notes
  - Looking a problem solutions



*Adapted from National Training Laboratories. Bethel, Maine

- They interpret a lack of specific assigned work as an invitation to do little or no active work

- Courses that penalize group success de-incentivize many important forms of active learning

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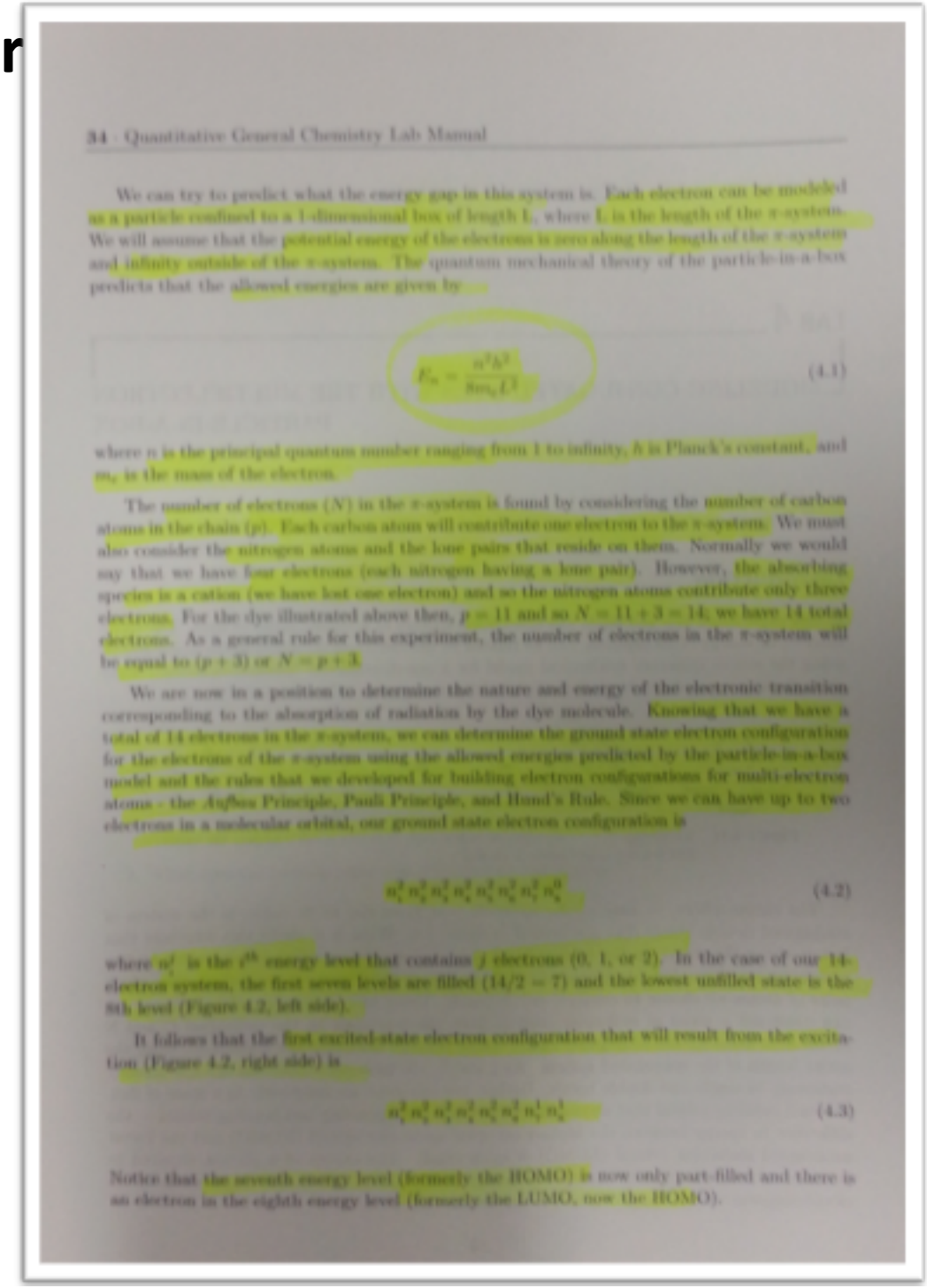
Our students cr



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We can try to predict what the energy gap in this system is. Each electron can be modeled as a particle confined to a 1-dimensional box of length L, where L is the length of the π-system. We will assume that the potential energy of the electrons is zero along the length of the π-system and infinity outside of the π-system. The quantum mechanical theory of the particle-in-a-box predicts that the allowed energies are given by

$$E_n = \frac{n^2 h^2}{8 m_e L^2} \tag{4.1}$$

where n is the principal quantum number ranging from 1 to infinity, h is Planck's constant, and m_e is the mass of the electron.

The number of electrons (N) in the π-system is found by considering the number of carbon atoms in the chain (p). Each carbon atom will contribute one electron to the π-system. We must also consider the nitrogen atoms and the lone pairs that reside on them. Normally we would say that we have four electrons (each nitrogen having a lone pair). However, the absorbing species is a cation (we have lost one electron) and so the nitrogen atoms contribute only three electrons. For the dye illustrated above then, $p = 11$ and so $N = 11 + 3 = 14$; we have 14 total electrons. As a general rule for this experiment, the number of electrons in the π-system will be equal to $(p + 3)$ or $N = p + 3$.

We are now in a position to determine the nature and energy of the electronic transition corresponding to the absorption of radiation by the dye molecule. Knowing that we have a total of 14 electrons in the π-system, we can determine the ground state electron configuration for the electrons of the π-system using the allowed energies predicted by the particle-in-a-box model and the rules that we developed for building electron configurations for multi-electron atoms - the *Aufbau* Principle, Pauli Principle, and Hund's Rule. Since we can have up to two electrons in a molecular orbital, our ground state electron configuration is

$$n_1^2\, n_2^2\, n_3^2\, n_4^2\, n_5^2\, n_6^2\, n_7^2\, n_8^0 \tag{4.2}$$

where n_i^j is the i^{th} energy level that contains j electrons (0, 1, or 2). In the case of our 14-electron system, the first seven levels are filled ($14/2 = 7$) and the lowest unfilled state is the 8th level (Figure 4.2, left side).

It follows that the first excited-state electron configuration that will result from the excitation (Figure 4.2, right side) is

$$n_1^2\, n_2^2\, n_3^2\, n_4^2\, n_5^2\, n_6^2\, n_7^1\, n_8^1 \tag{4.3}$$

Notice that the seventh energy level (formerly the HOMO) is now only part-filled and there is an electron in the eighth energy level (formerly the LUMO, now the HOMO).

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Goals for a hybrid model

- Remediate for missing pre-requisite knowledge / skills
- Engage students in active preparation for lecture
- Free-up lecture time for preconceptions, misconceptions, and deeper investigations
- Follow-up from lecture time with challenging problems to ensure that students are learning

Hybrid model in CH101/102 at Boston University

1. Prime students in lecture:
   - Give context and guidance
   - Set explicit expectations for learning outcomes (don't come back unless…)
2. Students work at home
   - Remediate for fundamental skills in math, physical science
   - Learn foundation skills to prepare for the next class
   - Cover basic topics to free up lecture time
3. Quiz students on their learning from work at home
4. Develop and extend during next lecture
   - Use class time to address confusion
   - Extended concepts
5. Integrated problem-solving and application of learning

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ALEKS is ideal for helping students prepare for class

- Prepare students through active preparation of
  - Fundamental, pre-requisite concepts
  - "Skill"-type topics that don't require lecture time
- One-on-one guidance of student effort eliminates challenges due to poor metacognitive sense
- Adaptive – students only do what they need
  - Remediation of foundation concepts only for students in need
  - Extra time on basics for students who struggle
  - Focus on areas of need for average students
  - Focus on ***mastery*** of concepts, not completion
- Stand-alone or completely eBook integrated

Addressing the need for remediation in preparation

Fall 2014 CH101 Cohort at Boston University

- 800+ students enrolled
- Mostly incoming freshmen
- Average SAT 1950
- Average high school GPA A^-

Good with basic arithmetic

Mathematics (93% Mastered)	Mastered	Not Mastered	Ready to Learn
Integer multiplication and division	99%	1%	1%
Simplifying a fraction	99%	1%	1%
Equivalent fractions	99%	1%	1%
Signed fraction multiplication: Advanced	95%	5%	4%
Signed decimal addition and subtraction with 3 numbers	98%	2%	1%
Finding a percentage of a whole number without a calculator: Basic	98%	2%	1%
Evaluating expressions with exponents: Problem type 1	97%	3%	2%
Ordering numbers with positive exponents	75%	25%	24%
Ordering numbers with negative exponents	79%	21%	20%

- Exponents are a problem for 20%+
- Similar problems with algebra and symbolic manipulation

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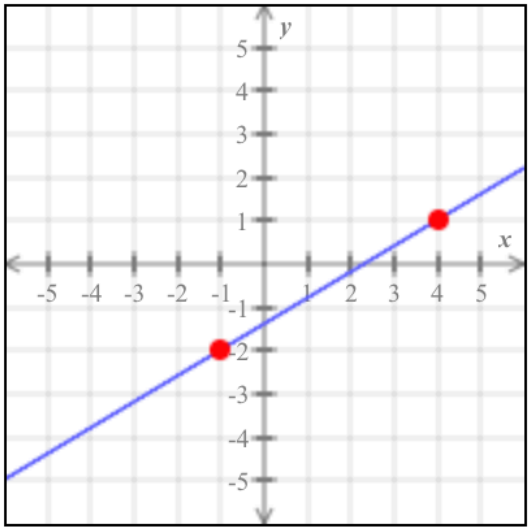
Graphing is a problem for 35%+

Graphing (73% Mastered)

Graphing a line given its equation in slope-intercept form	96%	4%	2%
Graphing a line through a given point with a given slope	64%	36%	27%
Determining the slope of a line given its graph	81%	19%	9%
Finding x- and y-intercepts of a line given the equation: Advanced	65%	35%	27%
Writing an equation of a line given the y-intercept and another point	61%	39%	20%

Determining the slope of a line given its graph

Find the slope of the line graphed below.



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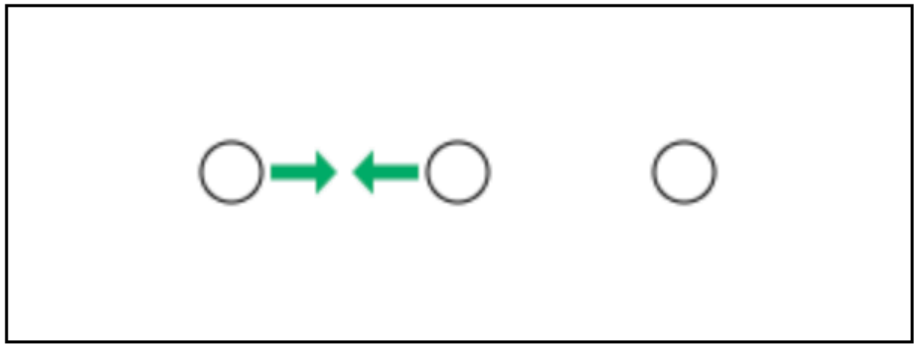
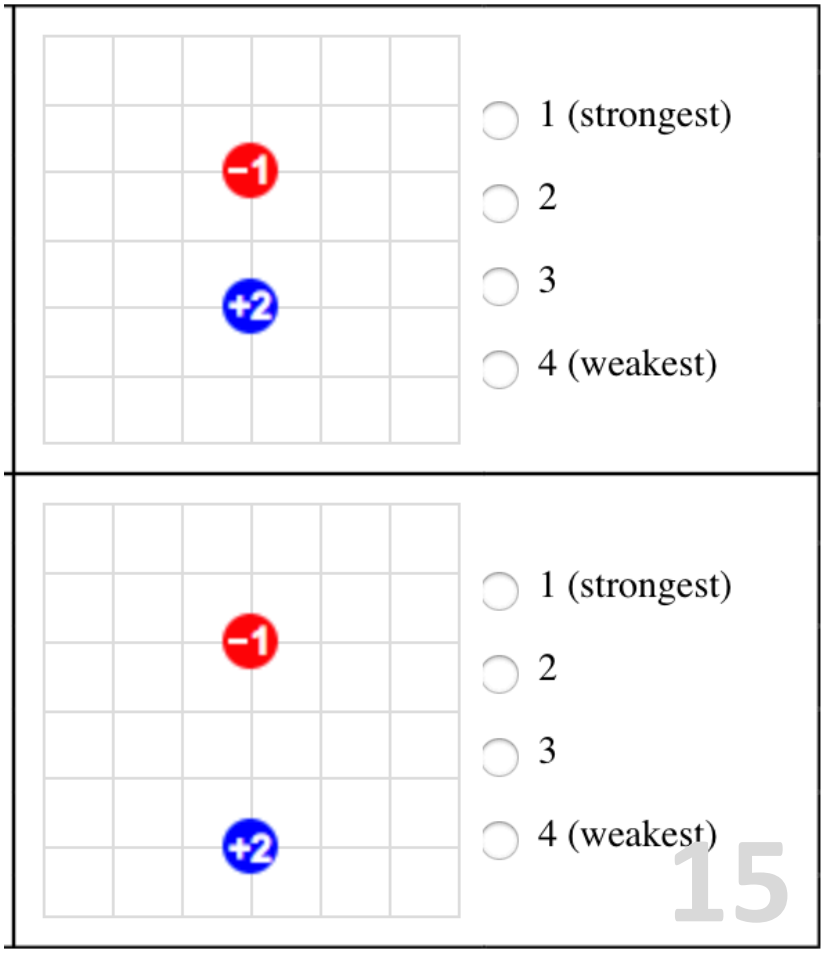
Almost all students struggle with electrostatics

Electrostatics (19% Mastered)

Understanding that opposite charges attract and like charges repel	31%	69%	69%
Understanding how electrostatic energy scales with charge and separation	7%	93%	25%





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Units and scientific notation are big problem areas

Scientific Notation (66% Mastered)	Mastered	Not Mastered	Ready to Learn
Multiplication of a decimal by a power of ten	96%	4%	4%
Division of a decimal by a power of ten	94%	6%	2%
Converting between decimal numbers and numbers written in scientific notation	86%	14%	9%
Multiplying and dividing numbers written in scientific notation	66%	34%	19%
Calculating positive powers of scientific notation	36%	64%	30%
Finding negative powers of scientific notation	19%	81%	15%

SI Units (26% Mastered)			
Knowing the dimension of common simple SI units	37%	63%	55%
Understanding the purpose of SI prefixes	32%	68%	59%
Knowing the value of an SI prefix as a power of 10	40%	60%	25%
Interconversion of prefixed and base SI units	28%	72%	0%
Interconversion of prefixed SI units	28%	72%	0%
Interconverting compound SI units	8%	92%	17%
Interconverting temperatures in Celsius and Kelvins	9%	91%	56%

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Units and scientific notation are big problem areas

Interconversion of prefixed and base SI units

An optician measures the diameter of her patient's pupil. The diameter is $0.0037\,\mathrm{m}$. What is the diameter in millimeters? Write your answer as a decimal.

Interconverting temperatures in Celsius and Kelvins

The metal mercury becomes superconducting at temperatures below $4.153\,\mathrm{K}$.

Calculate the temperature at which mercury becomes superconducting in degrees Celsius. Be sure your answer has the correct number of significant digits.

Students can't work with measurements in math

Measurement Math (34% Mastered)

Addition and subtraction of measurements	27%	73%	1%
Simplifying unit expressions	74%	26%	18%
Multiplication and division of measurements	0%	100%	7%

Measurement Uncertainty (22% Mastered)

Counting significant digits	26%	74%	57%
Rounding to a given significant digit	54%	46%	45%
Counting significant digits when measurements are added or subtracted	11%	89%	69%
Counting significant digits when measurements are multiplied or divided	15%	85%	38%
Adding or subtracting and multiplying or dividing measurements	2%	98%	9%

Multiplication and division of measurements

Decide whether each proposed multiplication or division of measurements is possible. If it *is* possible, write the result in the last column of the table.

proposed multiplication or division	Is this possible?	result
$\frac{140.\ \text{g}^2}{0.020\ \text{kg}} = ?$	○ yes ○ no	

Simple mass, volume, density relationships

Mass, Volume and Density (21% Mastered)	Mastered	Not Mastered	Ready to Learn
Estimating the volume in liters of a square prism object	28%	72%	3%
Finding the side length of a cube from its volume in liters	6%	94%	16%
Calculating volume by combining the volume of simple shapes	9%	91%	13%
Calculating mass density	34%	66%	11%
Using mass density to find mass or volume	28%	72%	15%

Using mass density to find mass or volume

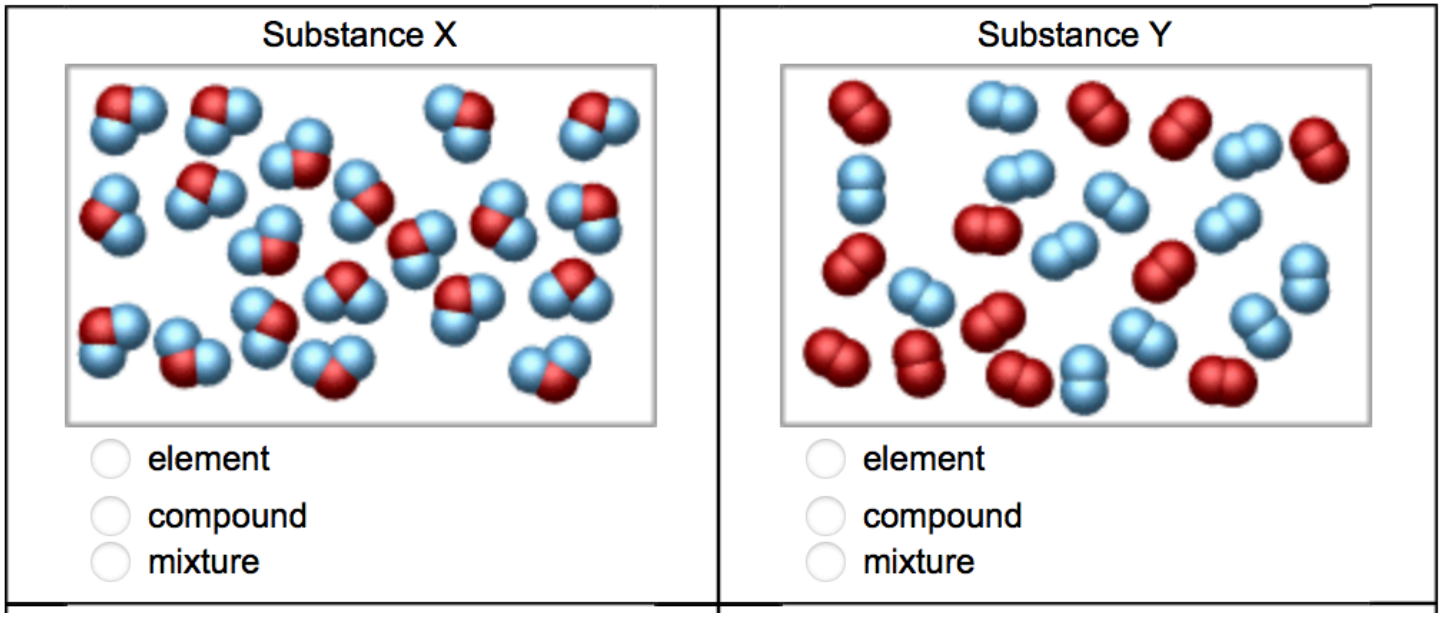
A chemistry student needs $85.0\,\mathrm{g}$ of acetone for an experiment. By consulting the *CRC Handbook of Chemistry and Physics*, the student discovers that the density of acetone is $0.790\,\mathrm{g} \cdot \mathrm{cm}^{-3}$. Calculate the volume of acetone the student should pour out.

Be sure your answer has the correct number of significant digits.

Basic principles from physical science

Atomic Theory (28% Mastered)

Distinguishing elements and compounds	65%	35%	34%
Distinguishing compounds and mixtures	20%	80%	45%
Distinguishing chemical and physical change	17%	83%	48%
Distinguishing solid, liquid and gas phases of a pure substance	12%	88%	87%



Summer Prep using ALEKS

- Prepare a pie with basic concepts (math, physical science)
- These are not concepts traditionally covered in other packages
- Set expectation of student-driven review of pre-requisites
- Get students working a little ahead of first week's lecture
- Due date

- 97% mastered by week 2
- 85%+ of students acknowledge benefit from using ALEKS

Course structure

- Summer assignment due after week 1
- Weekly ***Objectives*** due (each objective contains 5 – 20 topics)
- Periodic ***Assessments*** every 2 – 4 weeks (not more frequent)

- 10% of course credit for ALEKS
  - 5 x 1% for objective completion (effort = points)
  - 5% for end-of-course ***Mastery*** (knowledge = points)

Grade	% Students
D	3.7 ± 1.6
F	1.5 ± 0.7
W	9.1 ± 1.2
D/F/W	14.3% ± 2.3%

Average course grade: B-/C+

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Changes in lectures and office hours as a result of ALEKS

Representative questions from summer cohort (no ALEKS):

- What keeps NaCl(*s*) together?
- How do you write the formula for iron(III) sulfate?

Representative questions from fall cohort (students use ALEKS):

- Why aren't Na^+ and Cl^- ions attracted together in solutions?
- Why do iron atoms lose different numbers of electrons?

Questions?

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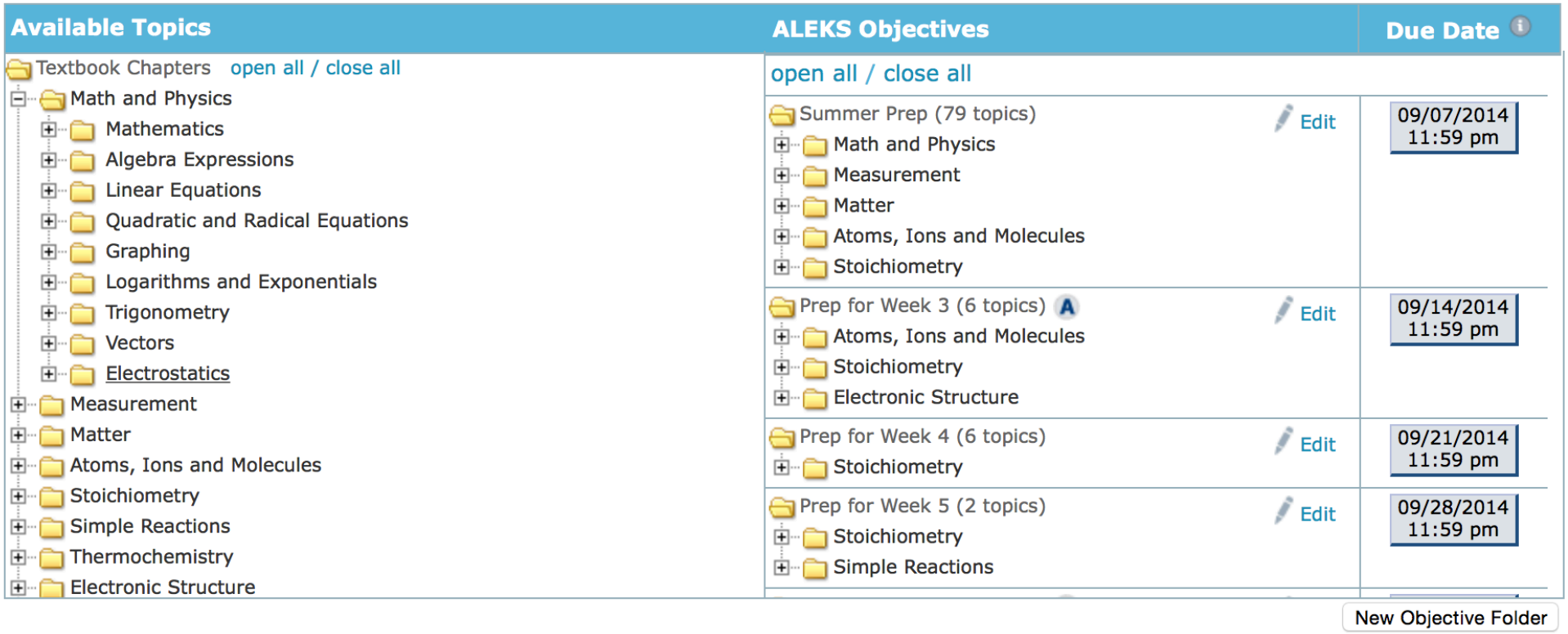
Objectives



Learning college chemistry is hard for most students

- Chemistry is frequently taken in 9th or 10th grade
- Few high school students are introduced to chemistry by properly-prepared educators
- Learning chemistry requires substantial fundamentals
  - Mathematics skills
  - Physics concepts
  - Basic chemistry skills
- Students have poor metacognitive sense
- All of the above create apprehension and anxiety about beginning college-level chemistry

Specific goals for summer ALEKS

- Review fundamentals for students not taking chemistry recently
- Homogenize elementary skills in math and physical science
- Give students confidence to prepare for class
- Emphasize the importance of problem solving and homework