10:30 - 11:10 Doing is Better than Watching

An example of an active learning approach for an engineering course will be presented. The entire class is devoted to answering conceptual questions using student response systems (clickers), peer instruction, and students working in pairs to solve partially-solved problems. Much of the learning occurs doing peer instruction, which means students discussing with and explaining to their fellow students. Unlike a traditional lecture, all students are engaged with this approach.

Liquid water is in vapor-liquid equilibrium with air at 1.2 bar in a piston-cylinder. The vapor volume is 3 cm$^3$. When 1 cm$^3$ of air is injected, pressure and temperature stay constant and the system goes to equilibrium. The mole fraction of air in the vapor ________.

A. increases
B. decreases
C. remains the same
\[ P = P_w + P_{air} \]
\[ 1.2 = P_{w}^{sat} + P_{air} \]

**Doing is Better than Watching**

John L. Falconer

University of Colorado Boulder

Example: Harvard chemistry professor
If you gave this problem to your class, what answer do you think they would select?

A constant-volume tank contains CO$_2$ at 2 bar. Nitrogen is injected into the tank isothermally. What happens to the CO$_2$ partial pressure if all the CO$_2$ remains in the tank. Assume ideal gases and an isothermal system.
A constant-volume tank contains CO₂ at 2 bar. Nitrogen is injected into the tank isothermally. What happens to the CO₂ partial pressure if all the CO₂ remains in the tank. Assume ideal gases and an isothermal system.

13  A. decreases
32  B. increases
6  C. stays the same  (chance is 17)
We want to separate 50/50 mixtures of C₆ isomers in the gas phase. As the temperature is lowered, your technician observes that n-hexane (n-C₆) condenses before 2,2-dimethylbutane (DMB). Can this happen?

A. Yes, if n-C₆ has a lower vapor pressure than DMB.
B. Yes, if n-C₆ has a higher vapor pressure than DMB.
C. No, because both species have to condense.
D. It depends on the system pressure; one or two species may condense.

\[ x_1 P_{1\text{sat}} = y_1 P \]
Liquid water is in equilibrium with air at 50°C in a piston-cylinder at 1 bar. The pressure is isothermally raised to 2 bar by pushing down on the piston. The water partial pressure ________.

A. increases
B. decreases
C. remains the same

Answers at beginning of semester in thermo

Liquid water is in equilibrium with air at 50°C in a piston-cylinder at 1 bar. The pressure is isothermally raised to 2 bar by pushing down on the piston. The water partial pressure ________.
Peer instruction

One of the best ways to improve understanding is to teach material to a peer.

Topping and Ehly, *Peer-assisted learning*, 1998

Even if students keep getting the answers wrong, so long as they’re given the correct information afterwards, the act of guessing is
actually likely to assist their learning.


Key elements is that students receive feedback while learning

President's Council Report 2012

**Using clickers**

- Students initially answer alone
- Don't show distribution of answers
- Discuss answers with neighbors and change answers
- Three points correct, two points incorrect (drop 5 days)

Not a good ConcepTest

QQ1.4.2. An ordinary vapor compression cycle is to be operated on propane (Cp/R=8.85,MW=44) to cool a chamber to 260K. Heat will be rejected to air at 308K. The temperatures in the coils are 256K and 312K. Estimate the work of compression (J/g).

<table>
<thead>
<tr>
<th></th>
<th>TK</th>
<th>PMPa</th>
<th>HL(J/g)</th>
<th>HV(J/g)</th>
<th>SL(J/g)</th>
<th>SLJ/gK</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>45</td>
<td>256</td>
<td>0.2707</td>
<td>482</td>
<td>879</td>
<td>4.131</td>
</tr>
<tr>
<td>B.</td>
<td>50</td>
<td>260</td>
<td>0.3108</td>
<td>490</td>
<td>883</td>
<td>4.158</td>
</tr>
<tr>
<td>C.</td>
<td>85</td>
<td>308</td>
<td>1.2150</td>
<td>619</td>
<td>935</td>
<td>4.585</td>
</tr>
<tr>
<td>D.</td>
<td>90</td>
<td>312</td>
<td>1.3350</td>
<td>624</td>
<td>942</td>
<td>4.600</td>
</tr>
</tbody>
</table>
What is the biggest mistake using clickers?

**ConcepTests**
- not too easy
- not calculations
- not memorization
- don’t contain non-essential information
- emphasize important concepts
- good wrong answers
- challenge students with qualitative questions
Why ConcepTests?

Students
- Learn from/teach other students
- Learn better if they teach others
- More engaged
- Get feedback on how well they understand
- Articulate their reasoning
- Motivated to be prepared
- Develop conceptual understanding and cognitive skills

In addition
- Attendance higher
- Encourages cooperation
- Instructor gets feedback from everyone
- More student-instructor interaction
Why clickers?

- Allow students to respond anonymously
- Safer for students to share their perspective and take risks
- Track responses to create accountability
- Increases student participation
- Students are more prepared to engage in discussion

Instead of clickers, can use phone:  https://kahoot.com/
Peer instruction improves learning (Hake, 1998)

Normalized gains

\[
\text{Normalized gains} = \frac{\text{final\%} - \text{initial\%}}{100\% - \text{initial\%}}
\]
Student feedback on ConcepTests

- “I cannot describe how much the active learning helps. I don’t think I have ever taken a class where I feel like I fully understand the information as well as I do in this one.”

- “Something you are doing that helps me learn are concept questions. They make me think about the problem and clear up concepts. A lot of times I think I will understand
something but I don’t really understand it and the concept questions help show me that.”

• “The clicker concept questions are great because they are interactive, which makes it easier to pay attention, and they are indicative of what you know and what you don’t know.”

• “I love the way you use clicker questions throughout the entire class rather than lecturing.”

• “The way I learn best is by making mistakes, so when I don’t know how to do the clicker questions, I end up learning much more than I would have if you ran the class in a lecture style format”

• “I would have to say that the format of your thermodynamics class was the most enjoyable and beneficial to my learning as a student. For the first two years… I became accustomed to the traditional lecture format that most professors utilize. It is very hard to pay attention and stay motivated in these type of class settings where we just sit for an hour and take notes while the professor rambles on about subjects we know little about.”

• “The interactive learning (clickers, etc.) is super helpful. It really helps me keep my attention in class.”

• "ConcepTests made me think thoroughly and completely about every subject."

• "I know a lot more now than I ever dreamed I would know. One of the biggest learning techniques was ConcepTests."

• "The most conceptually challenging ChE course I have had and the class I have been the most consistently motivated for."

• "I absolutely disliked clicker questions at the beginning, considering them tricky, but with time you learn to appreciate their point. Clicker questions actually are very beneficial."
What do the following have in common?

- hearing lectures
- reading textbooks
- solving quantitative problems
- seeing demos
- doing experiments

*L.C. McDermott, Am. J. Phys. 69, 1127 (2001)*
“Instructors work at perfecting their presentations. Our experience has shown that the effort involved does not result in significant gain for most students.

*L.C. McDermott, Am. J. Phys. 69, 1127 (2001)*

Which is a better way to learn to ski?
Solving partially-solved problems

Groups of two
One person explains, 2\textsuperscript{nd} person asks questions

The equilibrium conversion for the gas-phase reaction \( A(g) \rightleftharpoons 2 B(g) \) is 50.\% at 3.0-bar pressure. What is the equilibrium conversion at 6.0-bar pressure for a feed that is 50.\% A and 50.\% inert gas? Assume ideal gases.

Step 1: Write the equilibrium constant in terms of mole fractions and pressure

\[
A \rightleftharpoons 2B \quad \text{\( \text{K} = \left( \frac{n_B}{n_A} \right)^2 \rightleftharpoons \left( \frac{p_B}{p_A} \right)^2 \)}
\]

The standard state is an ideal gas at 1.0 bar.

Write \( K \) in terms of partial pressures.

\[
K = \quad \text{(expression for K in terms of partial pressures)}
\]

Write \( K \) in terms of mole fractions and total pressure.

\[
K = \quad \text{(expression for K in terms of mole fractions and total pressure)}
\]

Step 2: Determine the equilibrium constant from equilibrium at 3.0-bar pressure

\[
A \rightleftharpoons 2B
\]

\[
\begin{array}{c|c|c}
1.0 & 0 & \text{starting moles} \\
\hline
\text{moles at equilibrium in terms of } x & = & \text{moles at equilibrium in terms of } x
\end{array}
\]

Write \( y_A \) and \( y_B \) in terms of \( x \).

\[
y_A = \quad \text{expression for } y_A
\]
\[
y_B = \quad \text{expression for } y_B
\]

Write \( K \) in terms of \( x \) and \( P \).

\[
K = \frac{y_B^2}{y_A} = \quad \text{expression for } K
\]

Simplify.
Step 3: Determine extent of reaction at 6.0 bar pressure with feed 50.\% A, 50.\% inert

\[ A \rightarrow 2\, B \]

1.0 \, 0 \, start
1.0 - 3 \, 2 \times 3 \, equilibrium

Total moles at equilibrium = 

Write mole fractions in terms of extent

\[ y_A = \quad y_B = \]

\[ K = \frac{y_B^2 P}{y_A} = \]

Substitute values

Simplify to quadratic equation

\[ 7\, S^2 + 5\, S - 2 = 0 \]

\[ S = 0.46 \]

Increasing P:

Adding inert:

conclusion
At a certain temperature, the equilibrium constant is 20. for this reaction:

$$\text{C(s) + CO}_2(g) \rightleftharpoons \text{2CO(g)}$$

Initially, 0.50 mol of carbon and 1.0 mol of CO$_2$ are present at 2.0-bar pressure. What is the composition of the gas phase at equilibrium?

Write K in terms of activities, then in terms of fugacities and standard states:

$$K = \boxed{\quad} = \boxed{\quad}$$

Assume ideal gases, write K in terms of mole fractions:

$$K = \boxed{\quad}$$

$$\text{C(s) + CO}_2 \rightleftharpoons \text{2CO}$$

start 0.5 1.0 0

equilibrium \boxed{\quad} \leftarrow \text{in terms of extent of reaction}

total moles gas = \boxed{\quad}

mole fractions $$y_{\text{CO}_2} = \boxed{\quad} \quad y_{\text{CO}} = \boxed{\quad}$$

Write K in terms of $S$ and $P$, then simplify:

$$K = \frac{y_{\text{CO}}^2 P}{y_{\text{CO}_2}} = \boxed{\quad} = \boxed{\quad}$$

Substitute numerical values:

$$20 = \frac{4S^2(2)}{(1-S^2)} \Rightarrow 1 - S^2 = \frac{8}{20} \quad S^2 = 0.4S^2$$

$$1 = 1.4S^2$$

$$S = 0.845$$

Continued on back
Calculate moles and mole fractions

\[ \text{Constraint?} \]

\[ \therefore \quad z = \square \]

Moles CO\textsubscript{2} = \square

Moles CO = \square

\[ y_{\text{CO}_2} = \square \quad y_{\text{CO}} = \square \]