Solving Problems Using Problem Solving

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U. Guelph 1st-year Self-Test:

- Given the expression A/B = X/Y, then B is equal to:
  a) XY/A
  b) AY/X
  c) X/AY
  d) Y/AX

2008	2007	2006	2005
7.9%	6.9%		
68%	76%	76%	77%
18%	13%		
5.3%	4.4%		

Courtesy of Prof. Lori Jones, U. Guelph

U of T 2nd-Year Self-Test:

- When correctly expressed in SI units, a density of 1.23 g/cm^3 is:

a) 1.23 x 10^{-3} g/m^3
b) 1.23 x 10^{-3} kg/m^3
c) 1.23 g/m^3
d) 1.23 x 10^{3} kg/m^3

U of T 2nd-Year Self-Test:

- When correctly expressed in SI units, a density of 1.23 g/cm^3 is:

Wrong units

a) 1.23 x 10^{-3} g/m^3
b) 1.23 x 10^{-3} kg/m^3 ← Inverted conversion
c) 1.23 g/m^3
d) 1.23 x 10^{3} kg/m^3

2011	2010
9%	5%
19%	29%
4%	5%
68%	62%

U of T 2nd-Year Self-Test:

- Consider the following balanced chemical reaction:

$2\ MnO_4^- + 16\ H^+ + 15\ I^- \rightarrow 2\ Mn^{2+} + 5\ I_3^- + 8\ H_2O$

What volume of 0.0525 M I^- would be required to exactly react with 20.0 ml of 0.0125 M MnO_4^-?

a) 0.63 ml
b) 4.76 ml
c) 35.7 ml
d) 84.0 ml

U of T 2nd-Year Self-Test:

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$2\ MnO_4^- + 16\ H^+ + 15\ I^- \rightarrow 2\ Mn^{2+} + 5\ I_3^- + 8\ H_2O$

What volume of 0.0525 M I^- would be required to exactly react with 20.0 ml of 0.0125 M MnO

a) 0.63 ml ← inverted coefficients
b) 4.76 ml ← forgot the coefficients
c) 35.7 ml
d) 84.0 ml ← inverted concentrations

2011	2010
8%	7%
5%	19%
68%	72%
5%	2%

U. Guelph 1st-year Self-Test:

- The geometry of a water molecule is:
  - angular or bent ←
  - linear
  - pyramidal
  - tetrahedral

2008	2007	2006	2005
88.8%	85.2%	85%	85%
4.5%	5.7%		
4.6%	5.9%		
2.1%	3.2%		

Courtesy of Prof. Lori Jones, U. Guelph

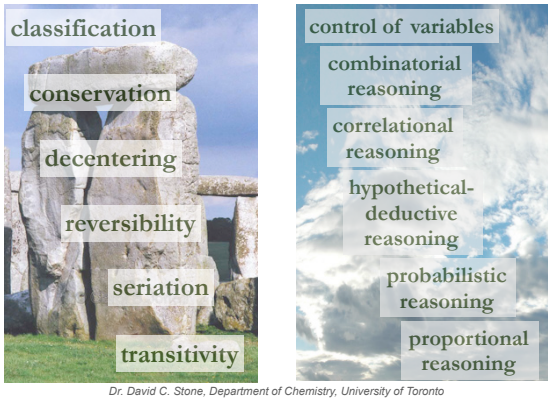
U. Guelph 1st-year Self-Test:

- The geometry of a molecule in which the central atom is bonded to 2 H atoms and
  - tetrahedral
  - angular or bent ←
  - linear
  - pyramidal

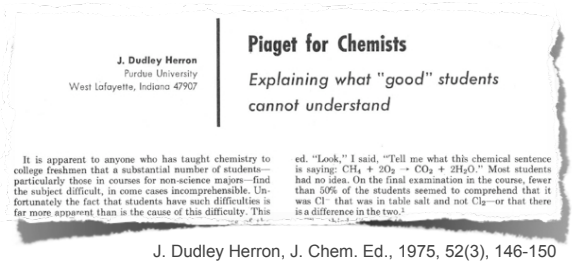
2008	2007	2006	2005
15.9%	16.4%		
53.0%	52.8%	54%	54%
13.9%	12.8%		
17.2%	18.1%		

Courtesy of Prof. Lori Jones, U. Guelph

Ways of thinking (Piaget):



Piagetian Development:



J. Dudley Herron
Purdue University
West Lafayette, Indiana 47907

Piaget for Chemists

Explaining what "good" students cannot understand

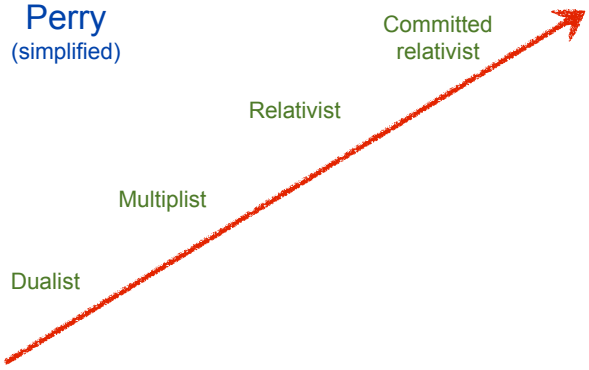
It is apparent to anyone who has taught chemistry to college freshmen that a substantial number of students—particularly those in courses for non-science majors—find the subject difficult, in come cases incomprehensible. Unfortunately the fact that students have such difficulties is far more apparent than is the cause of this difficulty. This

ed. "Look," I said, "Tell me what this chemical sentence is saying: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$." Most students had no idea. On the final examination in the course, fewer than 50% of the students seemed to comprehend that it was Cl^- that was in table salt and not Cl_2—or that there is a difference in the two.[1]

J. Dudley Herron, J. Chem. Ed., 1975, 52(3), 146-150

- HS+ chemistry needs "formal operational development"
- Good proportion of 1st-year students "not there yet"

Ways of knowing:



Dualism versus relativism:

Acid–base theories

Lewis – electron transfer

$$Cu^{2+}_{aq} + NH_3 \rightleftharpoons \left[Cu(NH_3)\right]^{+}_{aq}$$

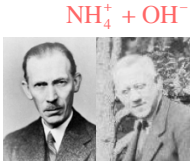
Brønsted-Lowry – proton transfer (hydrolysis)

Arrhenius – dissociation

$$HCl_{aq} \longrightarrow H^{+}_{aq} + Cl^{-}_{aq}$$

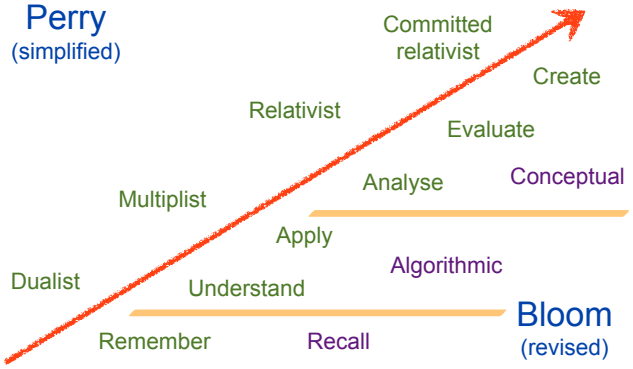
$$NH_3 + HOH \rightleftharpoons NH_4^+ + OH^-$$

Litmus



boric acid

Ways of knowing:



Troublesome Knowledge

- David Perkins:

"Some students will resort to rote memory and routine procedures ... They will try to learn enough ... to pass the test without developing any real insider feel. And pass they may, ending up with knowledge troubled by partial and brittle understandings ..."

in Overcoming Barriers to Student Learning, chapter 3, emphasis added

Alternate Conceptions:

"If anomalous new information is presented in a learning situation where the student is rewarded (with grades) for remembering it, the information *may be memorized* in order to earn the reward, but it is likely to be quickly forgotten because it *does not make sense*"

Douglas Mulford & William Robinson
J. Chem. Ed. 2002, 79(6), 739-744 (emphasis added)

Alternate Concepts

- "Common sense" reasoning
- Intuitive thinking
- Personal experience
- Mental shortcuts ("cognitive misers")
- Misuse of analogies (inappropriate or limits not stated)
- Misunderstanding of the nature of scientific models
- The way we teach and grade assessments

Rationality (Piaget redux)

- A bat and a ball cost $1.10. The bat costs $1 more than the ball. How much does the ball cost?

a) 10 cents
b) 5 cents
c) other amount

Keith E. Stanovich, *Sci. Amer. Mind*, 2009, Nov/Dec., 34-39

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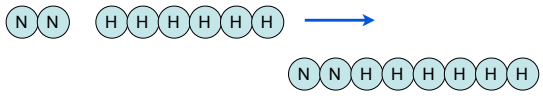
Alternate Concepts

- Balance the following equation for the production of ammonia:

$$N_2 + H_2 \rightarrow NH_3$$

- Represent the balanced reaction using circles with letters in the centre to depict the atoms:



Equals vs. Equivalent?

- There are six times as many students as professors at a particular university. This can be expressed mathematically as:
  - $6S = P$ Equivalent "units" of students & professors
  - $S = 6P$ Calculation of students from professors

At a particular university there are six times as many students as professors. This fact is represented by the equation S = 6P. What does the letter S stand for?

Equals vs. Equivalent?

- Stoichiometry:

$$a\,A + b\,B \rightarrow c\,C + d\,D$$

$$n = \frac{PV}{RT}$$

$$n = CV \rightarrow \frac{n_A}{n_B} = \frac{a}{b} \therefore n_A = n_B \times \frac{a \text{ moles of A}}{b \text{ moles of B}}$$

$$n = \frac{m}{M_m}$$

Alternate Conceptions

- What do the following symbols indicate?

H H_2 H^+

Conceptual Problems

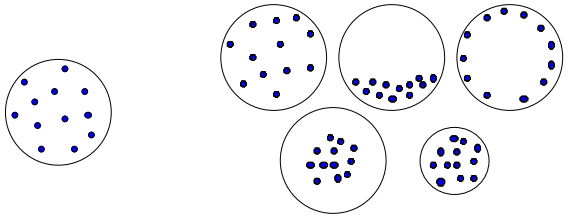
- Individual 0.200 g samples of each of the following gases were placed in four separate 1.00 L stoppered flasks at 298 K. In which flask do you expect the gas to exert more pressure? Explain your answer.

Flask:	A	B	C	D
Gas:	CH_4	Ne	N_2	CO_2
M_m (g/mol)	16.0	20.2	28.0	44.0

Lillian Bird, JCE 2010

Algorithmic & Conceptual

- The following diagram represents a cross-sectional view of a rigid sealed tank...



Good problems, bad problems...

- Two questions:
  - What is the pH of an acid?
  - What is the pH of 1.0×10^{-8} mol/L of HCl?

The Problem with Problem-Solving

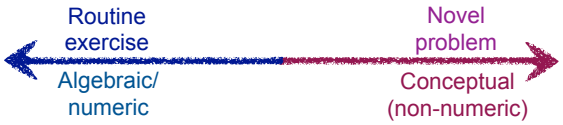
- John Hayes:

  "Whenever there is a gap between where you are and where you want to be, and you don't know how to find a way to cross that gap, you have a problem."

- G. H. Wheatley:

  "What you do, when you don't know what to do"

Both cited by Bodner, U. Chem. Ed. 2003



Problem-Solving Activities

- Groups of ~ 3–4 people
- Appoint an observer to record the process!
- Solve a problem (10 minutes):
  - The Waterfall Problem
  - The Pizza Problem
  - The Water and Wine Problem
  - The Xenon Fluoride Problem