Solving Problems Through Problem Solving

Jerry Scott and Jim Borgman, http://www.arcamax.com/zits/

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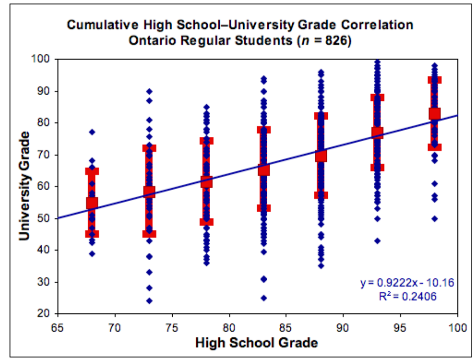
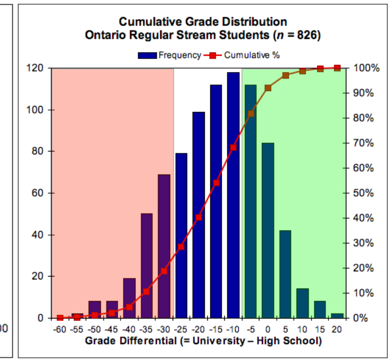
First-year triumph & trauma:





– 25% of students drop 30-60 % points from HS
– Complex reasons for this!

http://www.chem.utoronto.ca/~dstone/Research/survey.html

The journey:

ASSIST/SPQ

Deep

Create

Strategic

Evaluate

Conceptual

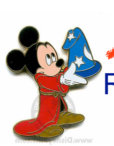
Analyse

Apply

Algorithmic

Surface

Understand



Remember

Recall

Bloom (revised)

Multiple-choice assessments:

- Diagnostic
- Formative
- Summative

– The first part of a multiple-choice question is the:

a) item
b) leaf
c) node
d) stem

(a–c: distractors; same length/style; logical order)

$$P_{q,i} = 1 : i^q$$

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

2012	2011	2010
17%	9%	5%
20%	19%	29%
3%	4%	5%
61%	68%	62%

Units and unit prefixes:

- At a minimum, drill:
  - cgs ↔ mks (SI)
  - p, n, μ, m, c, d, k, M, G
  - unit analysis for *sanity checking*

- There are six times as many students as professors at a particular university. This can be expressed mathematically as:
  - 6S = P # students *equivalent* to 1 professor
  - S = 6P # students *equals* multiple of # professors

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

2012	2011	2010
8%	8%	7%
8%	5%	19%
77%	68%	72%
6%	5%	2%

Stoichiometric calculations:

- Strongly recommend the Mole Ratio!
  - law of definite proportions

$$aA + bB \rightarrow pP + qQ$$

MOLE RATIO!

$$\frac{n_A}{n_B} = \frac{a}{b} \quad \therefore n_A = n_B \frac{a}{b}$$

n_A → $\frac{m}{M_m}$, n_A → CV, n_A → $\frac{PV}{RT}$

U of T 2nd-Year Self-Test:

- A solution of known iodine concentration may be prepared by mixing solutions of iodate and iodide under acidic conditions:

$$a\, IO_3^- + b\, I^- + c\, H^+ \rightarrow p\, I_2 + q\, H_2O$$

When correctly balanced, the stoichiometric coefficients in this reaction equation are: atoms only

a) $a = 1, b = 1, c = 6, p = 1, q = 3$

b) $a = 1, b = 5, c = 6, p = 3, q = 3$

c) $a = 3, b = 3, c = 6, p = 3, q = 3$ charge only

d) $a = 5, b = 1, c = 6, p = 1, q = 5$

2012	2011	2010
44%	52%	52%
48%	41%	42%
6%	6%	7%
2%	0%	0%

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U of T 2nd-Year Self-Test:

- A 500 ml sample of a solution contains 0.375 moles of HNO_3. Assuming no other acidic species are present, the pH of the solution is:

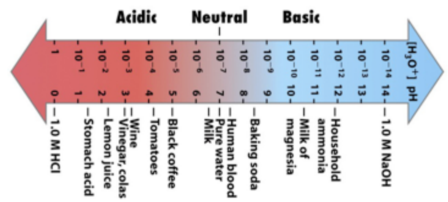
a) pH = 0.125

b) pH = 0.426 ← ignored volume

c) pH = 0.727 ← divided by 2 (!)

d) the pH cannot be less than 1

2012	2011
70%	68%
18%	11%
3%	7%
8%	12%



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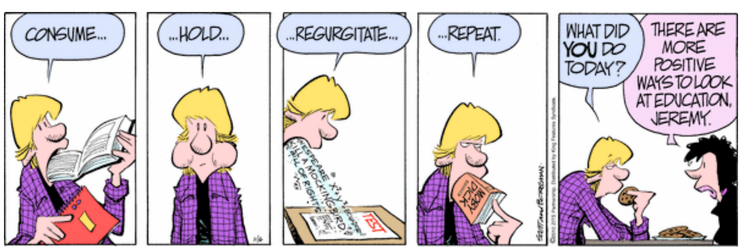
Write your own:

- Form groups of ~3
- Acid-base/Precipitation/Units question
  - m/c format with four items (a)–(d)
  - distractors should be common errors
  - share your question & critique validity



Jerry Scott and Jim Borgman, November 6th 2010
http://www.arcamax.com/zits/

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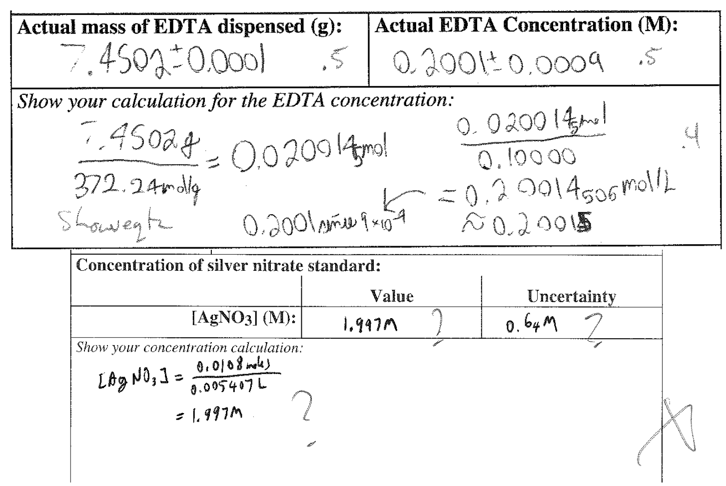
Multistep calculations (algorithmic):

- Do calculation & *show your work!*



Actual mass of EDTA dispensed (g):	Actual EDTA Concentration (M):
7.4502±0.0001 .5	0.2001±0.0009 .5

Show your calculation for the EDTA concentration:

7.4502 g / 372.24 g/mol = 0.020014 mol

0.020014 mol / 0.10000 = 0.20014 mol/L ≈ 0.2001

Concentration of silver nitrate standard:	Value	Uncertainty
[AgNO3] (M):	1.997 M ?	0.64 M ?

Show your concentration calculation:

[AgNO3] = 0.0108 mol / 0.005407 L = 1.997 M ?

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Multistep calculations (algorithmic):

- Do calculation & *show your work!*
  1. write out needed equations
  2. combine & rearrange, etc.
  3. substitute values *with* units
  4. check units cancel correctly
  5. calculate answer to *correct s.f.*
  6. does final value *look* reasonable?
     - *why is your answer correct?*
     - *what assumption(s) did you make?*

Algorithmic and conceptual m/c:

- 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	CO_2	N_2	Ne
M_m (g/mol)	16.0	44.0	28.0	20.2

Lillian Bird, *J. Chem. Ed.*, **2010**, 87(5), 541-546

Algorithmic and conceptual m/c:

- Four flasks of equal volume are filled with equal masses of different gases (one gas per flask) and sealed. If all four are held at exactly the same temperature, which contains gas at the greatest pressure?

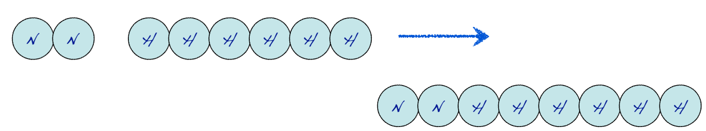
	2012	2011
a) Carbon dioxide (CO_2), M_m = 44 g/mol	12%	25%
b) Methane (CH_4), M_m = 16 g/mol	74%	61%
c) Neon (Ne), M_m = 20 g/mol	2%	2%
d) Nitrogen (N_2), M_m = 28 g/mol	0%	1%
e) Cannot be determined	11%	10%

There are no bad questions (?)

- 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:



There are no bad questions (?)

- Two questions:
  - What is the pH of an acid?
  - What is the pH of 1.0×10^{-8} mol/L of HCl?
- Follow-up:
  - Can a solution ever have a *negative* pH?

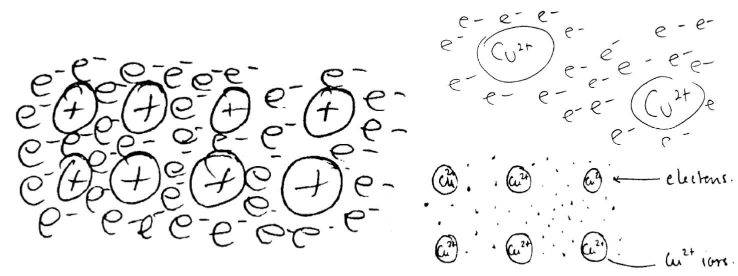
Acid	$[H^+]$
37% HCl	12 M
70% HNO_3	16 M
85% H_3PO_4	15 M
96% H_2SO_4	~36 M

There are no bad questions (?)

- What do the following symbols indicate?

  (a) H (b) H_2 (c) H^+

- Sketch a diagram to represent the metallic bonding present in a block of solid copper:



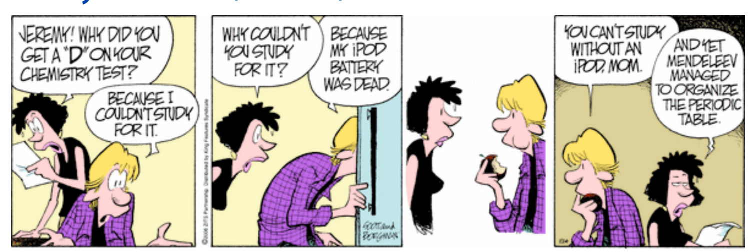
Keith S. Taber, *Science Education*, **2003**, *87(5)*, 732-758

Alternate conceptual formats:

- Description of experiment, phenomenon, *etc.*
  - Mark the following explanations as either:
    - (T) True; (F) False; (I) Irrelevant
    - (E) Explains; (D) Does not explain; (I) Irrelevant
- Many compounds of the transition metals Sc through Zinc have characteristic colours, both as solids and in solution. This is attributed to splitting of the 3d atomic orbitals. For example, aqueous $CuSO_4$ is a cyan colour because:
  - When an electron drops down from an upper to a lower 3d orbital, the emitted photon has a wavelength in the blue region of the spectrum
  - When an electron is excited from a lower to an upper 3d orbital, the absorbed photon has a wavelength in the red region of the spectrum
  - The increased size of the cation caused by the splitting makes it large enough to scatter blue light out of solution, much like particles in the atmosphere

Alternate conceptual formats:

- Description of experiment, phenomenon, *etc.*
  - Mark the following explanations as either:
    - (T) True; (F) False; (I) Irrelevant
    - (E) Explains; (D) Does not explain; (I) Irrelevant
- Roll your own, share, evaluate!



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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

Routine exercise ⟵⟶ Novel problem

Algebraic/ numeric — Conceptual (non-numeric)

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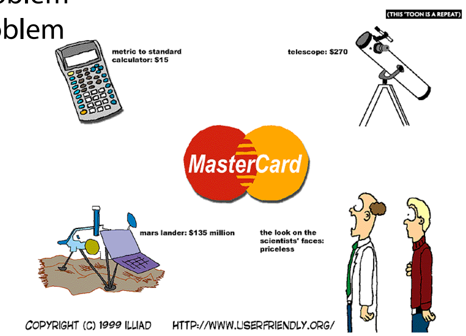
Problem-Solving Activities

- Groups of ~ 3–4 people
- Appoint an observer to record the process!
- Solve a problem, recording *how you did so*:
  1. The Waterfall Problem
  2. The Pizza Problem
  3. The Water and Wine Problem
  4. The Xenon Fluoride Problem
  5. The Train Problem



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The assessment: