Solving Problems Using Problem Solving

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Piagetian Development:

Concrete operational:	Formal operational:
classification	control of variables
conservation	combinatorial reasoning
decentering	correlational reasoning
reversibility	hypothetical-deductive reasoning
seriation	probabilistic reasoning
transitivity	proportional reasoning

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%		
68.4%	75.7%	76%	77%
18.4%	13.0%		
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:

Wrong units

a) 1.23 x 10^{-3} g/m^3 4.8%
b) 1.23 x 10^{-3} kg/m^3 28.6%
c) 1.23 g/m^3 4.8%
d) 1.23 x 10^3 kg/m^3 61.9%

Inverted conversion

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 iodide would be required to exactly react with 20.0 ml of 0.0125 M permanganate?

a) 0.63 ml **7.0%** ← **inverted coefficients**
b) 4.76 ml **18.6%** ← **forgot the coefficients**
c) 35.7 ml **72.1%**
d) 84.0 ml **2.3%** ← **inverted concentrations**

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:

a) $a = 1, b = 1, c = 6, p = 1, q = 3$ **51.2%** ← mass only
b) $a = 1, b = 5, c = 6, p = 3, q = 3$ **41.9%**
c) $a = 3, b = 3, c = 6, p = 3, q = 3$ **7.0%** ← charge only
d) $a = 5, b = 1, c = 6, p = 1, q = 5$ **0.0%**

U. Guelph 1st-year Self-Test:

- The geometry of a water molecule is:
  a) angular or bent ←
  b) linear
  c) pyramidal
  d) 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 molecule in which the central atom is bonded to 2 H atoms and has 2 lone pairs is:
  a) tetrahedral
  b) angular or bent ←
  c) linear
  d) 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

Threshold Concepts

- Jan Meyer & Ray Land:
  "[Are] akin to a portal, opening up a new and previously inaccessible way of thinking ... without which the learner *cannot progress*"
  in *Overcoming Barriers to Student Learning*, chapter 1, emphasis added

- moles & stoichiometry
- heat & temperature
- atoms & properties
- chemical bonds
- molecular geometry
- particles & kinetic theory
- equilibrium processes
- reaction kinetics

Equals *vs.* Equivalent?

There are six times as many students as professors at a particular university. This can be expressed mathematically as:

a) 6S = P Equivalent "units" of students & professors
b) 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:

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

- mass is conserved
- compounds have definite proportions of elements

∴ stoichiometric reaction requires definite ratios of compounds

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

Alternate Concepts

- What do the following symbols indicate?

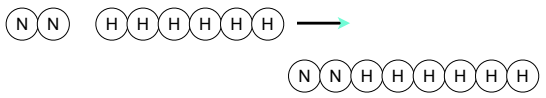
$$\mathrm{H} \qquad \mathrm{H_2} \qquad \mathrm{H^+}$$

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:



Alternate Concepts

- A metallic wire has the following properties:
  a) conducts electricity
  b) brown colour
  c) density of 8.93 g/cm^3
  d) malleable & ductile
  e) expands on heating

  Suppose you could isolate one single atom from the metallic wire: which of the above properties would it have?

Alternate Concepts

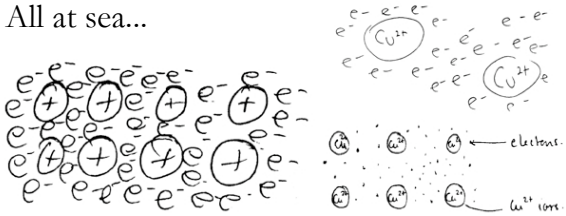
- The wire is heated in an evacuated vessel until it completely evaporates. The resulting gas has the following properties:
  a) compressible
  b) expands on heating
  c) pungent odour
  d) yellow colour
  e) attacks plastics

  Suppose you could isolate one single atom from this gas: which of the above properties would it have?

Alternate Conceptions:

- Bonding and Properties
  – metallic bonding poorly understood

All at sea...



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

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

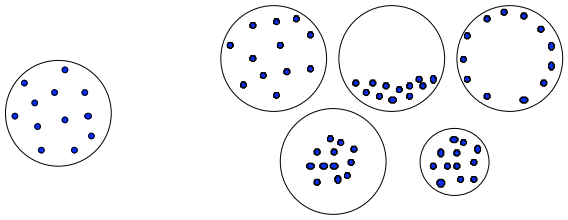
Conceptual Problems

- Four identical sealed containers are filled with a different gas as indicated below until each contains exactly the same mass. If all four are held at the same temperature, which flask contains gas at the greatest pressure?

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

Algorithmic & Conceptual

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

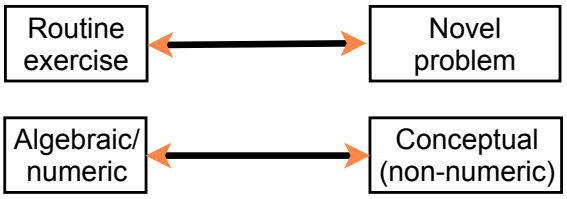


Problem-Solving

- G. H. Wheatley:

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

as 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