Maths in Science

1. What is the difference between procedural and declarative knowledge?

2. How should the nature of knowledge affect the decisions you make about its teaching?

3. Case study: How I use cognitive science findings to teach mathematics in science?

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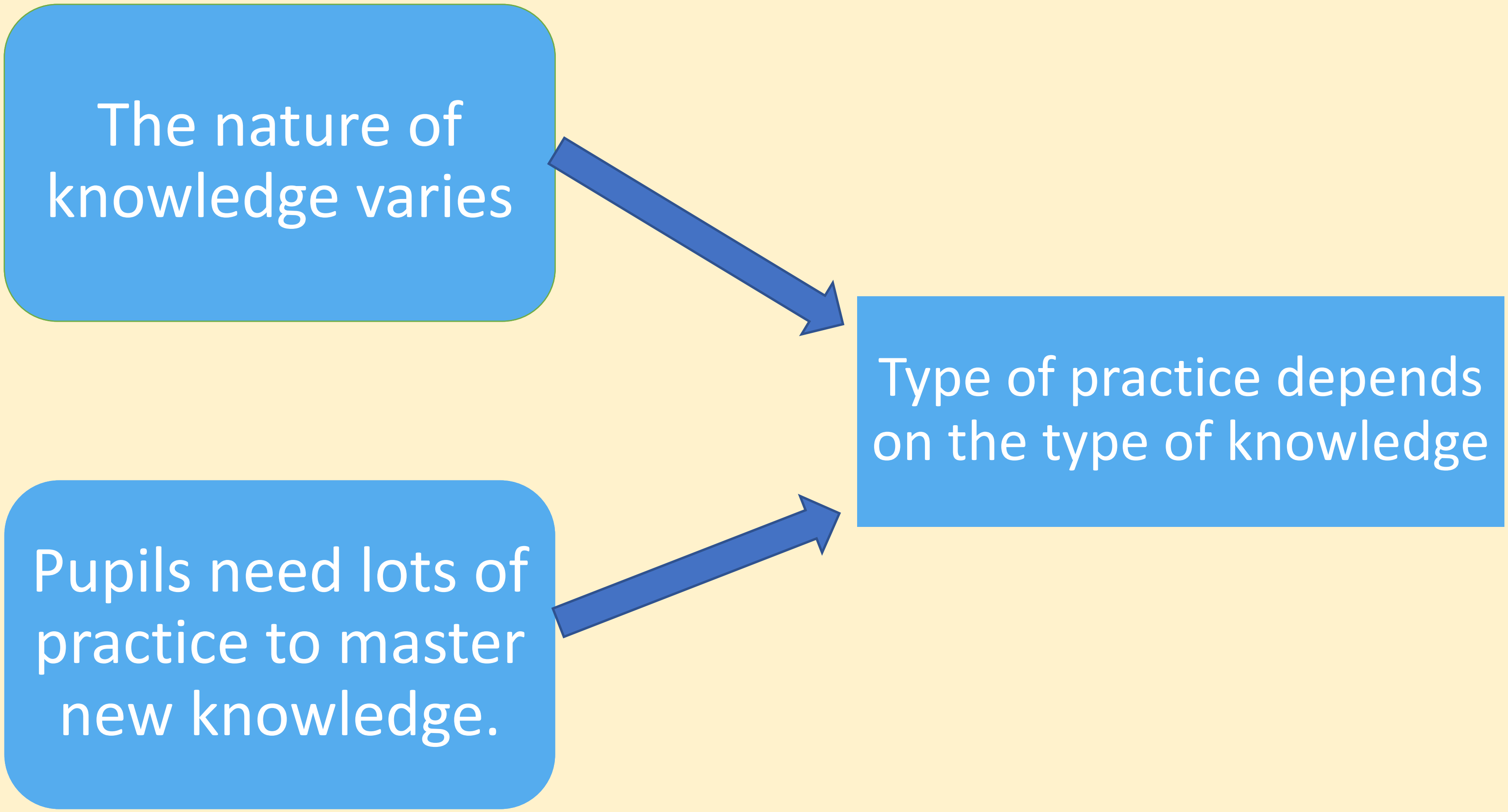
Knowledge and Practice



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Procedural vs Declarative

Declarative: *know that*

- Substances are made out of atoms
- Atoms have mass
- W stands for Weight

Procedural: *know how*

- Steps for performing a calculation
- Drawing an ion from an atom (add brackets and charge)

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Decisions for Teaching

Knowing that '*performing calculations*' is **procedural knowledge** can help us make decisions about its teaching:

1. Teach necessary declarative knowledge explicitly

2. Break down procedural knowledge into constituent steps

3. Worked examples

4. Scaffolding: faded examples & misconceptions

5. Interleaved practice

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Principle 1: Declarative Knowledge

- What does the calculation represent?
- What facts are needed to perform and understand calculation?
- Issue - complex web:
  - Wait for mastery, or move to procedural?

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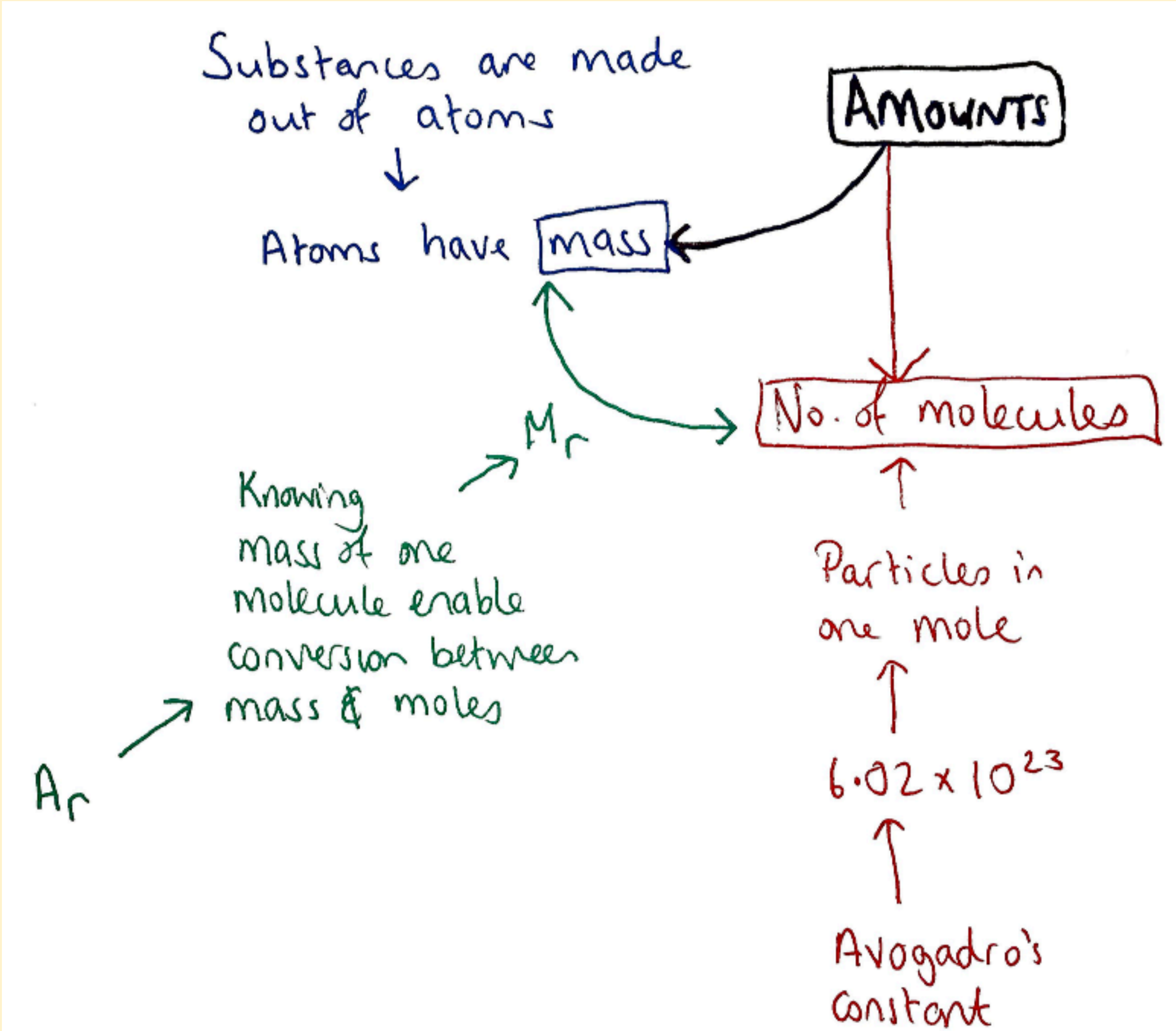
Substances are made out of atoms
Atoms have mass
AMOUNTS
No. of molecules
Mr
Knowing mass of one molecule enable conversion between mass & moles
Ar
Particles in one mole
6.02 x 10^23
Avogadro's constant

Principle 2: Procedural Steps

- Simplest possible steps
- Pupils don't need names or descriptions if complex

1. Box the value to be calculated & underline given values
2. List all values, with units
3. Write equation which unites values
4. Check units – convert if necessary
5. Substitute
6. Combine values if possible, then rearrange
7. Calculate final answer & write units.

$n = ?\ mol$

$m = 88\ g$

$M_r = 12 + (2 \times 16)$

$= 12 + 32$

$= 44$

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

$n = \frac{88}{44}$

$n = \underline{\underline{2\ mol}}$

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Principle 2: Procedural Steps

- Practice components separately at first
  - Drill: state the standard unit for each variable
  - Drill: convert these into standard units
- Then combine

Teacher: What is the symbol for current?
Pupil: I
Teacher: Capital or lower case?
Pupil: Upper case.
Teacher: What are the units for current?
Pupil: Amps
Teacher: What letter can we use for the units of current?
Pupil: Capital A.

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Principle 3: Worked Examples

- Visualiser
- 1st time: no questions; 2nd time: questions
    - Standardise the format
    - Hand-written examples in textbook

Calculating moles examples [D]

Carbon dioxide (CO_2) and carbon monoxide (CO) can both be made by reacting carbon with oxygen. Relative atomic masses (A_r): C = <u>12</u>, O = <u>16</u>. Calculate the number of moles of <u>88 g</u> of carbon dioxide (CO_2).

$n = ?\ \text{mol}$

$m = 88\ g$

$M_r = 12 + (2 \times 16)$

$= 12 + 32$

$= 44$

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

$n = \frac{88}{44}$

$n = \underline{\underline{2\ \text{mol}}}$

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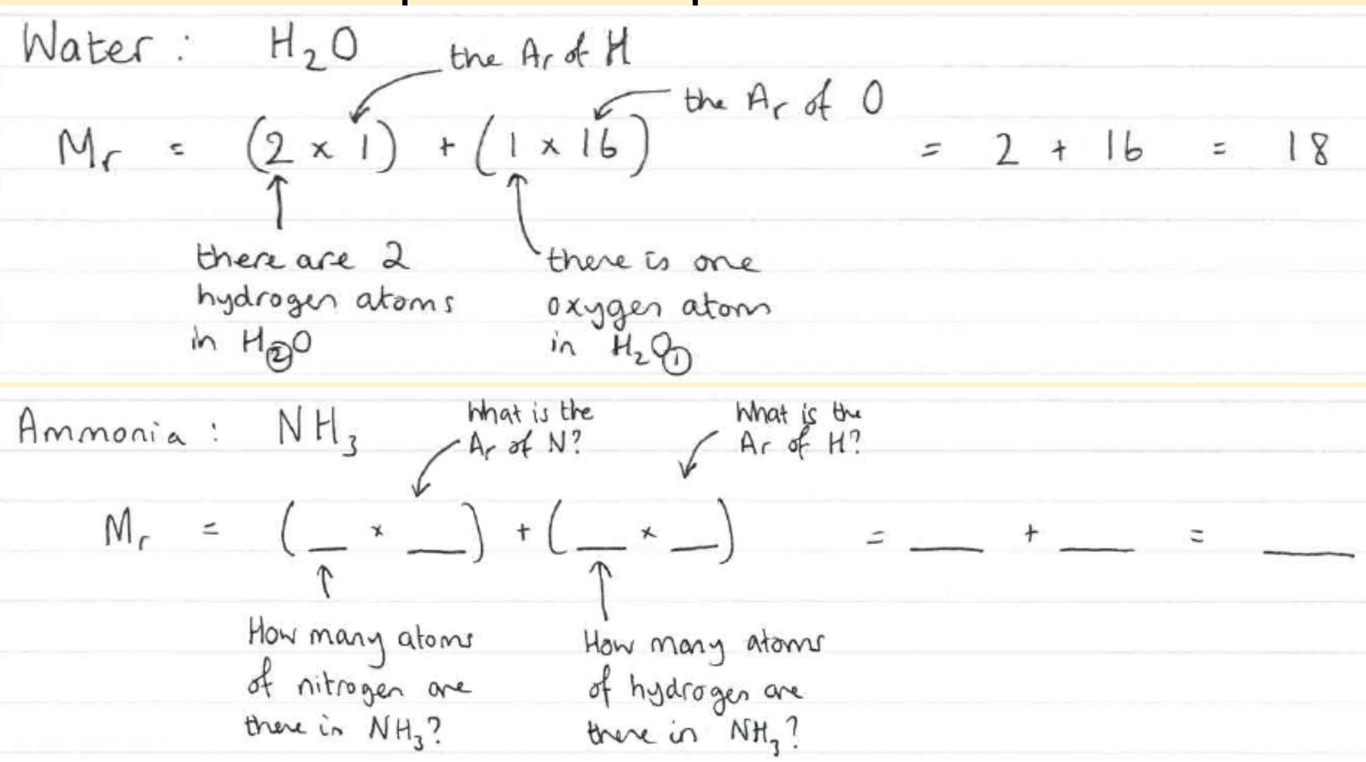
Principle 4: Scaffolded Practice

- Faded examples enable the practice of one component at a time
- Labelled examples → faded
- Misconception examples



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Principle 4: Scaffolded Practice

- Faded examples enable the practice of one component at a time
- Labelled examples → faded
- Misconception examples

Calcium carbonate : $CaCO_3$

M_r = ___ + ___ + (___ × ___)

= ___ + ___ + ___

= ___

Nitrogen : N_2

M_r = (2 × ___)

= ___

Top tip: always put the number of atoms first

Nitric acid : HNO_3

M_r = ___ + ___ + (3 × ___)

= ___ + ___ + ___

= ___

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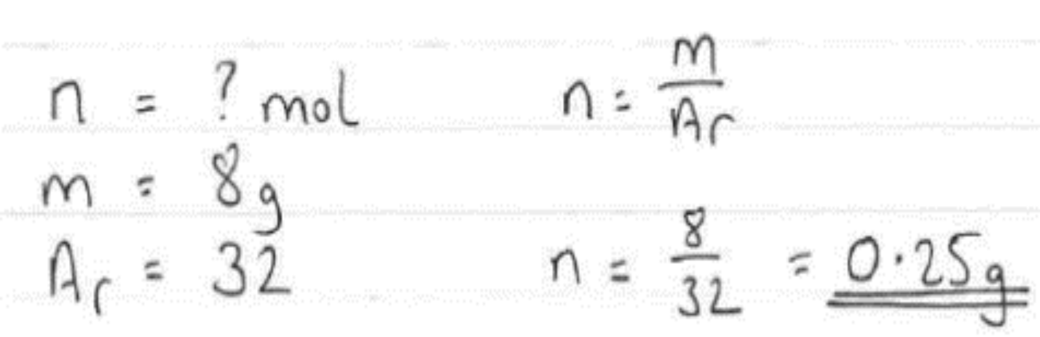
Principle 4: Scaffolded Practice

- Faded examples enable the practice of one component at a time
- Labelled examples → faded
- Misconception examples

Calculate the number of moles in 8 g of sulphur.
Spot the mistake!



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BUG

Calculate the mass of sodium nitrate ($NaNO_3$) that will be made using 17g of sodium oxide.

a

$$Na_2O + 2HNO_3 \rightarrow 2NaNO_3 + H_2O$$

b

17g ? g

c

1 : 2

(Na_2O)

d

$n = ?$ mol

$m = 17$g

$M_r = (2 \times 23) + 16$

$= 46 + 16$

$= 62$

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

$n = \frac{17}{62} = 0{\cdot}27419...$

$n = 0{\cdot}2742$ mol

e

1 : 2

0·2742 mol 0·548 mol

($NaNO_3$)

f

$n = 0{\cdot}548$ mol

$m = ?$ g

$M_r = 23 + 14 + (3 \times 16)$

$= 23 + 14 + 48$

$= 85$

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

$0{\cdot}548 = \frac{m}{85}$

$m = 0{\cdot}548 \times 85$

$= 46{\cdot}58$ g

$\approx 46{\cdot}6$ g

BUG Calculate the mass of calcium chloride produced when 7.4 grams of calcium hydroxide ($Ca(OH)_2$) reacts with excess hydrochloric acid.

a $Ca(OH)_2 + HCl \rightarrow CaCl_2 + 2H_2O$

b [ ] g   [ ] g

c ___ : ___

$Ca(OH)_2$

d

n =

m =

M_r =

___ : ___

e ___ : ___

$CaCl_2$

f

n =

m =

M_r =

BUG

Calculate the mass carbon monoxide (CO) that can be made from 5 grams of carbon.

a

$2C + O_2 \rightarrow 2CO$

b

☐ g ☐ g

c

___ : ___

d

n =

m =

M_r =

e

___ : ___

___ : ___

f

n =

m =

M_r =

BUG

Calculate the mass of glucose a plant can make if it has 24 grams of carbon dioxide and an excess of water.

a

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

b

c

n =

d

m =

M_r =

e

n =

f

m =

M_r =

Principle 5: Interleave / Mixed Practice

- > 2 formula? … Mix it up!
- Practice crucial step: selection of correct formula

Equation number	Word equation	Symbol equation
1	weight = mass × gravitational field strength (g)	$W = m\,g$
2	work done = force × distance (along the line of action of the force)	$W = F\,s$
3	force applied to a spring = spring constant × extension	$F = k\,e$
4	distance travelled = speed × time	$s = v\,t$
5	acceleration = $\frac{\text{change in velocity}}{\text{time taken}}$	$a = \frac{\Delta v}{t}$
6	resultant force = mass × acceleration	$F = m\,a$
7 HT	momentum = mass × velocity	$p = m\,v$
8	kinetic energy = 0.5 × mass × (speed)^2	$E_k = \frac{1}{2} m\,v^2$
9	gravitational potential energy = mass × gravitational field strength (g) × height	$E_p = m\,g\,h$
10	power = $\frac{\text{energy transferred}}{\text{time}}$	$P = \frac{E}{t}$
11	power = $\frac{\text{work done}}{\text{time}}$	$P = \frac{W}{t}$
12	efficiency = $\frac{\text{useful output energy transfer}}{\text{total input energy transfer}}$	
13	efficiency = $\frac{\text{useful power output}}{\text{total power input}}$	
14	wave speed = frequency × wavelength	$v = f\,\lambda$
15	charge flow = current × time	$Q = I\,t$
16	potential difference = current × resistance	$V = I\,R$
17	power = potential difference × current	$P = V\,I$
18	power = (current)^2 × resistance	$P = I^2\,R$
19	energy transferred = power × time	$E = P\,t$
20	energy transferred = charge flow × potential difference	$E = Q\,V$
21	density = $\frac{\text{mass}}{\text{volume}}$	$\rho = \frac{m}{V}$

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Final thoughts

- Procedural before mastery of declarative:

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Final thoughts

For moles, the declarative knowledge is:

1. All substances - matter - are made out of atoms.
2. All atoms have mass.
3. To describe the amount of a substance - such as water - we can either:
   1. Count the number of water molecules
   2. Measure the mass of the substance
   3. (Measure the volume of a substance)
4. Mass and number of molecules are both valid ways of describing amounts, but are useful or appropriate for different reasons.
5. Measuring the mass of a substance can be used to calculate the number of molecules of that substance, provided that we know the mass of one molecule.
6. The total mass divided the mass of one molecule tells us the number of molecules.
7. The known mass of each particle is known as the relative atomic mass (Ar) for single atoms, and relative formula mass (Mr) for molecules (or ratios). The periodic table supplies us with this information.
8. Avogadro's constant is used to define one mole: 6.02 x 10^23 molecules.
9. Avogadro's constant helps us to write numbers of molecules more concisely, since everyday amounts of substances exceed this number of particles.
10. So, number of moles is another way of saying number of molecules.
11. Therefore: mass (m); number of moles (n); and relative formula mass (Mr) are related to each other: n=m/Mr
12. In this way, the two ways of describing amounts of a substance: number of molecules and mass, are interchangeable.

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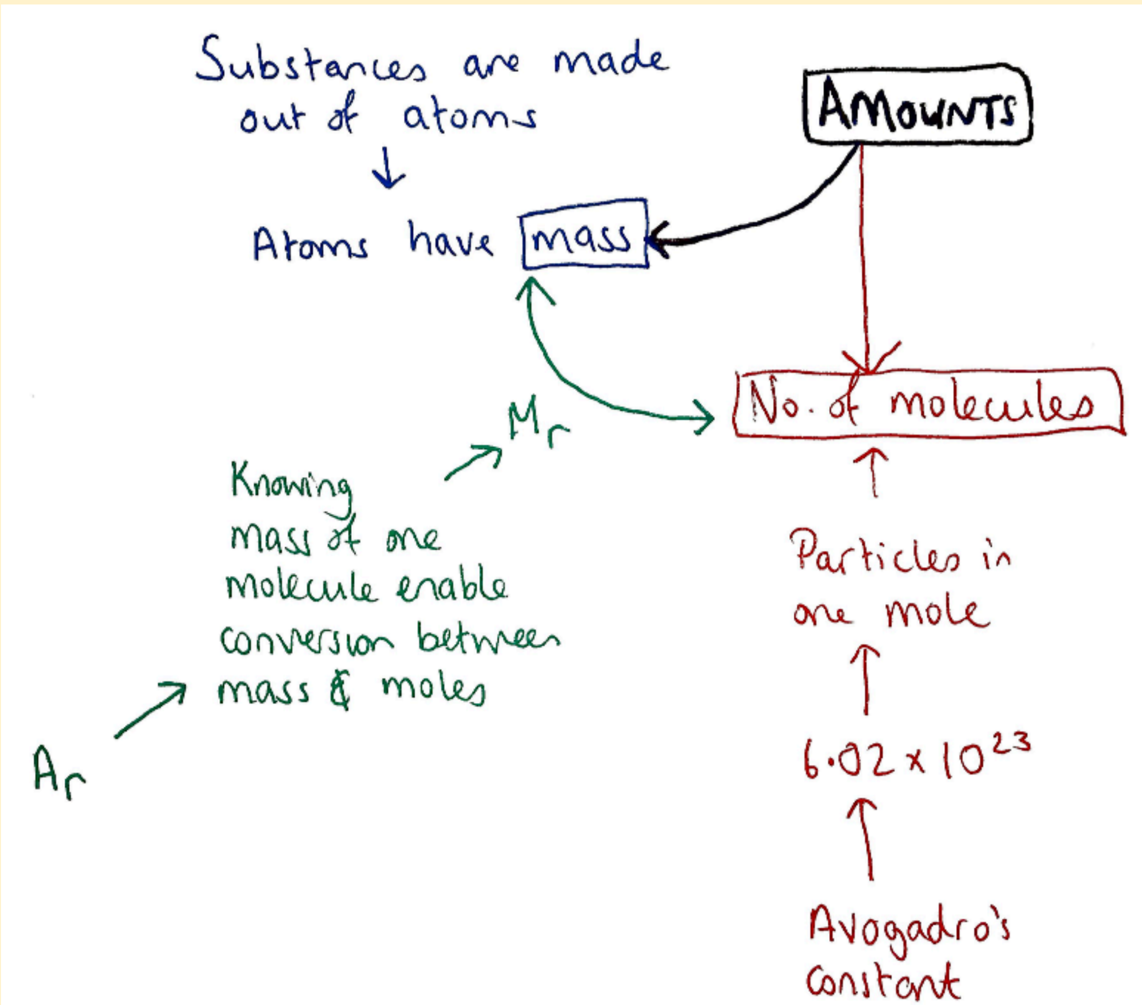
Final thoughts

- Procedural before mastery of declarative… **dual-coding?**



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

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References

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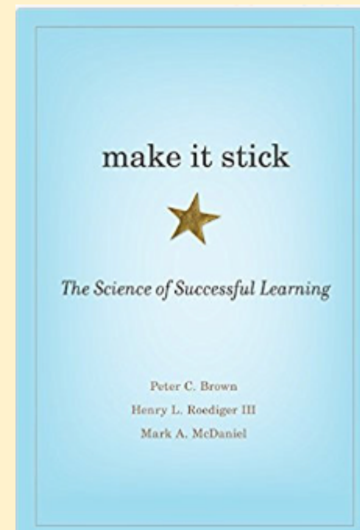

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Questions?

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