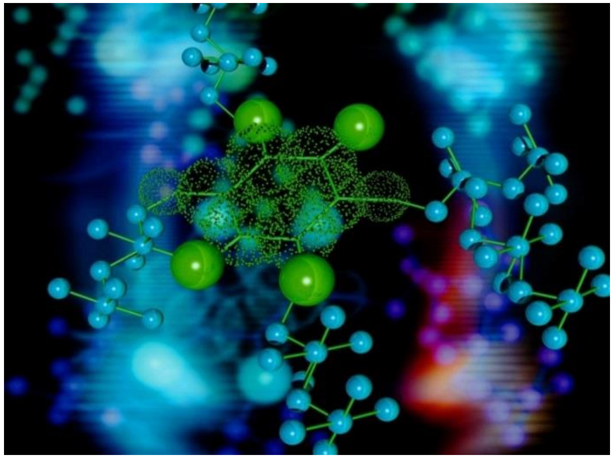
TEACHING AND LEARNING CHEMISTRY

Why is it so difficult?

CHEMISTRY – WHAT'S IT ALL ABOUT?



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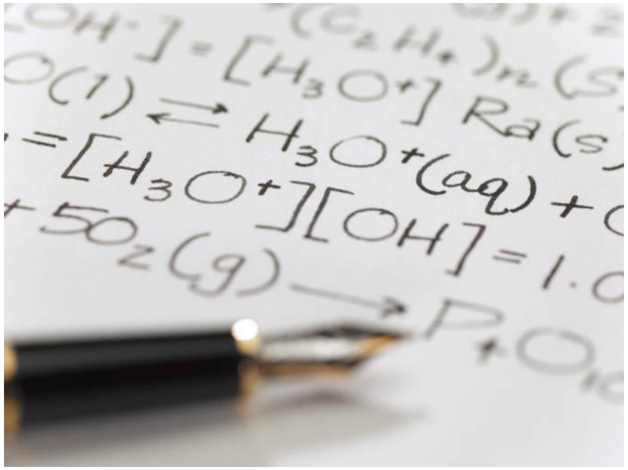

C.

D.

DISCUSSION QUESTIONS

What is Chemistry?

Why do students find it so difficult to learn chemistry?

Alex H Johnstone

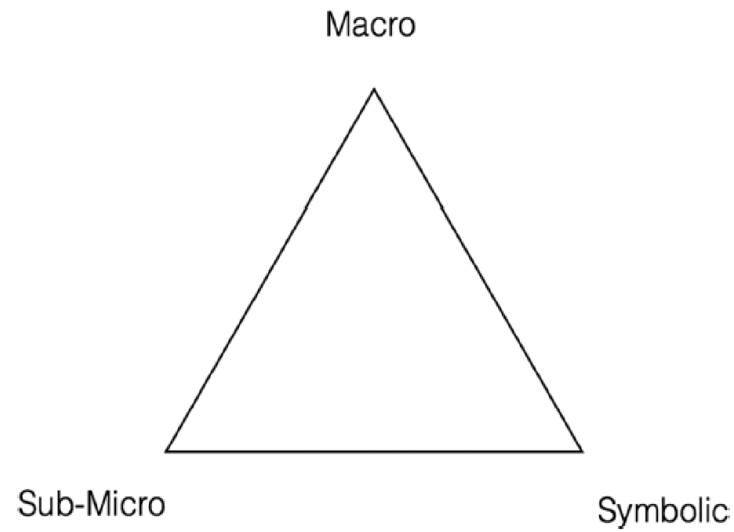

Figure 1. Johnstone's triangle, representing multilevel thought in chemistry. Adapted with permission from ref 65. Copyright 1991 John Wiley & Sons, Inc.

Students have difficulty learning in science is because science requires multi levels of thinking.

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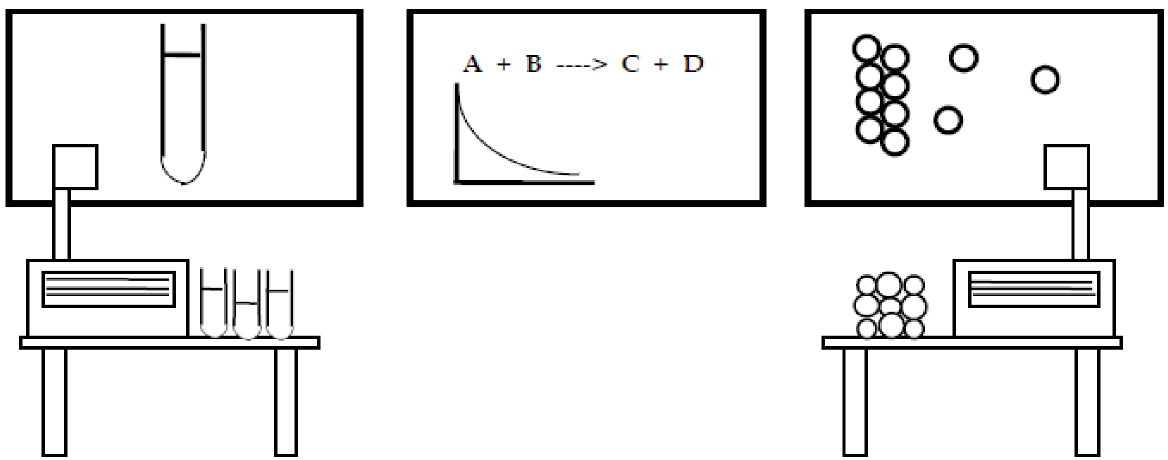
Johnstone's Three Thinking Levels

Observable Level (concrete, real)	Symbolic Level (abstract, mathematical)	Molecular Level (spatial, imaginary)

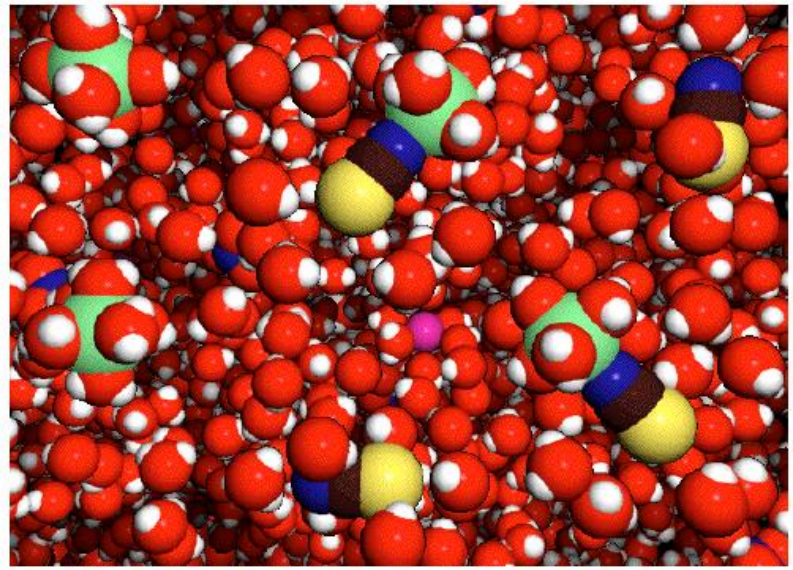


Johnstone, A. H. (1991) Why is science difficult to learn?
Journal of Computer-Assisted Learning, 7, 75 - 83

VisChem animations of molecular world

Observable Level

Molecular Level

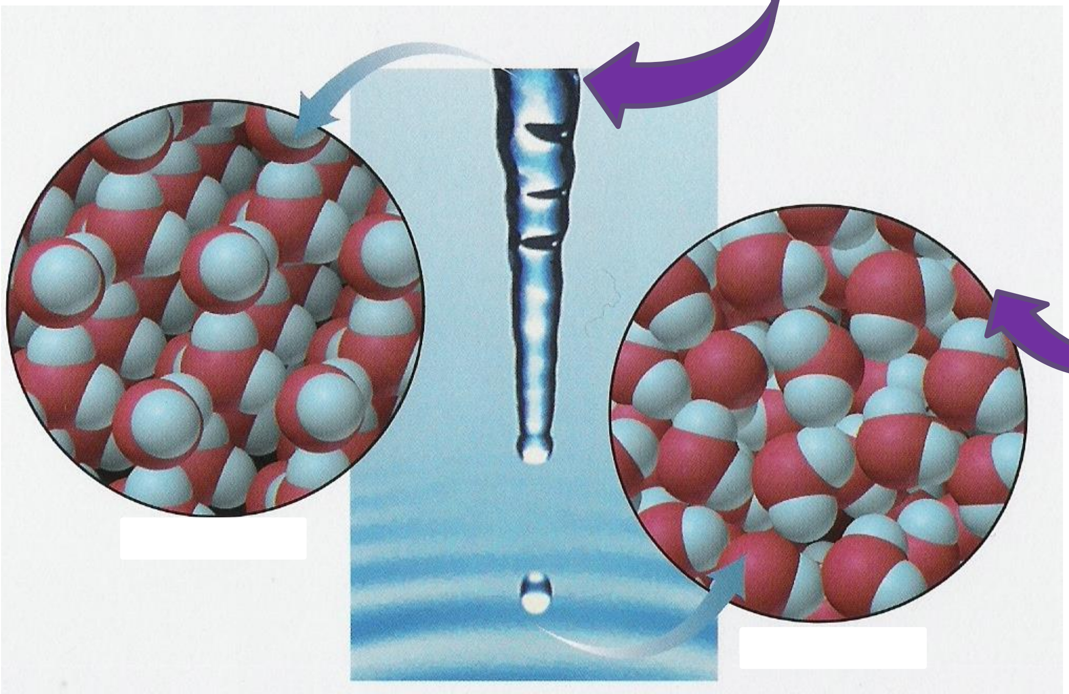


Symbolic Level

$[FeSCN]^{-}(aq) \qquad Fe^{3+}(aq) + SCN^{-}(aq)$

MACROSCOPIC / OBSERVATIONS
- chemical and physical properties
- chemical reactions
- physical changes
- quantitative measurements

PARTICLES:
- thinking about atoms/ions/molecules
- nature of particles present – atoms/ions/molecules
- interactions between particles
- changes to particles or numbers of particles
- chemical principles and laws e.g. gas laws



SYMBOLS:
formulae, equations

$$H_2O(s) \longrightarrow H_2O(\ell)$$

ThinkChem
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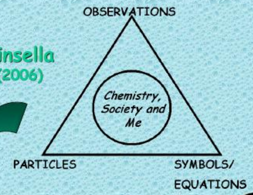
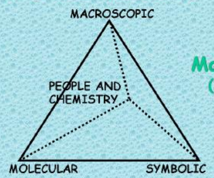
the learner is the focus

Kinsella (2006)



the human perspective

Mahaffy (2004)



OBSERVATIONS

Using this poster:

- The ideas presented in this poster were developed to support teachers in identifying the **pedagogy of chemistry** – how chemistry is taught and learned, and how current practice could evolve
- In the classroom, use this poster to make **explicit** to students the interplay between the conceptual levels. Refer to the poster as you (or the students) move from ***observations*** ➔ ***particles*** ➔***symbols***, so that students can make the links between the **familiar** and the **abstract**
- Use **models** (to help form mental images) and **'real life' examples** (to make chemistry relevant) in order to support student learning

Adding the human perspective and grounding chemistry in real world problems and solutions:

- Historical, economic, political, environmental, social, philosophical and personal considerations
- The nature of chemistry – its language and customs in investigating and solving problems

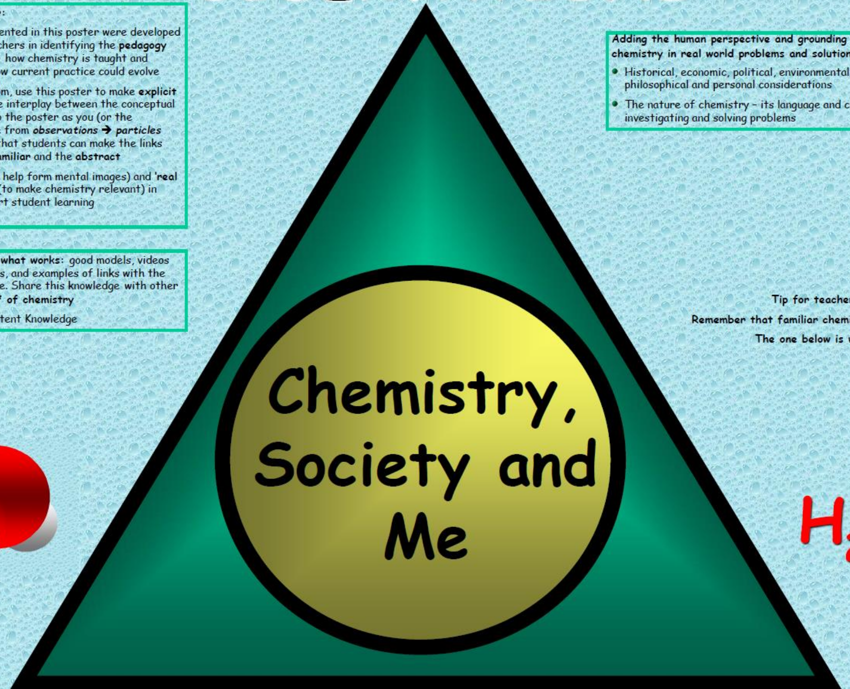
Keep records of what works: good models, videos and web resources, and examples of links with the human perspective. Share this knowledge with other teachers ➔ **PCK* of chemistry**

* Pedagogical Content Knowledge

Tip for teachers:

Remember that familiar chemicals have names…

The one below is water!



H_2O

PARTICLES

SYMBOLS/ EQUATIONS

Johnstone's conceptual levels:

- *Macroscopic* – observations of the materials around us, including properties, reactions and measurements.
- *Molecular* (or sub-micro) – the particles (atoms, molecules and ions) and the structures and interactions present.
- *Symbolic* (or representational – the symbols, formulae, equations, graphs etc. that have been developed to represent chemical concepts.

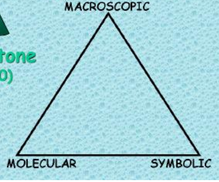
Bruner's modes of knowledge:

- *Enactic* knowledge – derived from physical action
- *Iconic* knowledge – derived from forming and organising images
- *Symbolic* knowledge – derived from use of language in terms of words and other symbols

Specifying the structure of chemistry knowledge

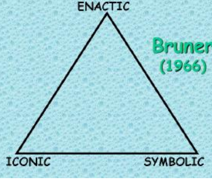
conceptual levels of chemistry

Johnstone (2000)



modes of knowledge

Bruner (1966)



ACHIEVEMENT AIMS

Nature of science

Students will:

Communicating in science

Develop knowledge of the vocabulary, numeric and **symbol systems, and conventions** of science and use this knowledge to communicate about their own and others' ideas.

Material world

Students will:

Properties and changes of matter

Investigate the **properties** of materials.

The structure of matter

Interpret their observations in terms of **the particles** (atoms, molecules, ions, and sub-atomic particles), structures, and interactions present.

Understand and use fundamental concepts of chemistry.

Chemistry and society

Make connections between the concepts of chemistry and their applications and show an understanding of the role chemistry plays in the world around them.

Note: Most learning experiences for chemistry will require that all three aims are studied together. Observations are explained by considering the structures and interactions of the component particles and linked to the applications of chemistry in everyday life.

DISCUSSION QUESTIONS

What are the implications of the ‘triangle’ for teaching and learning in our chemistry classes?

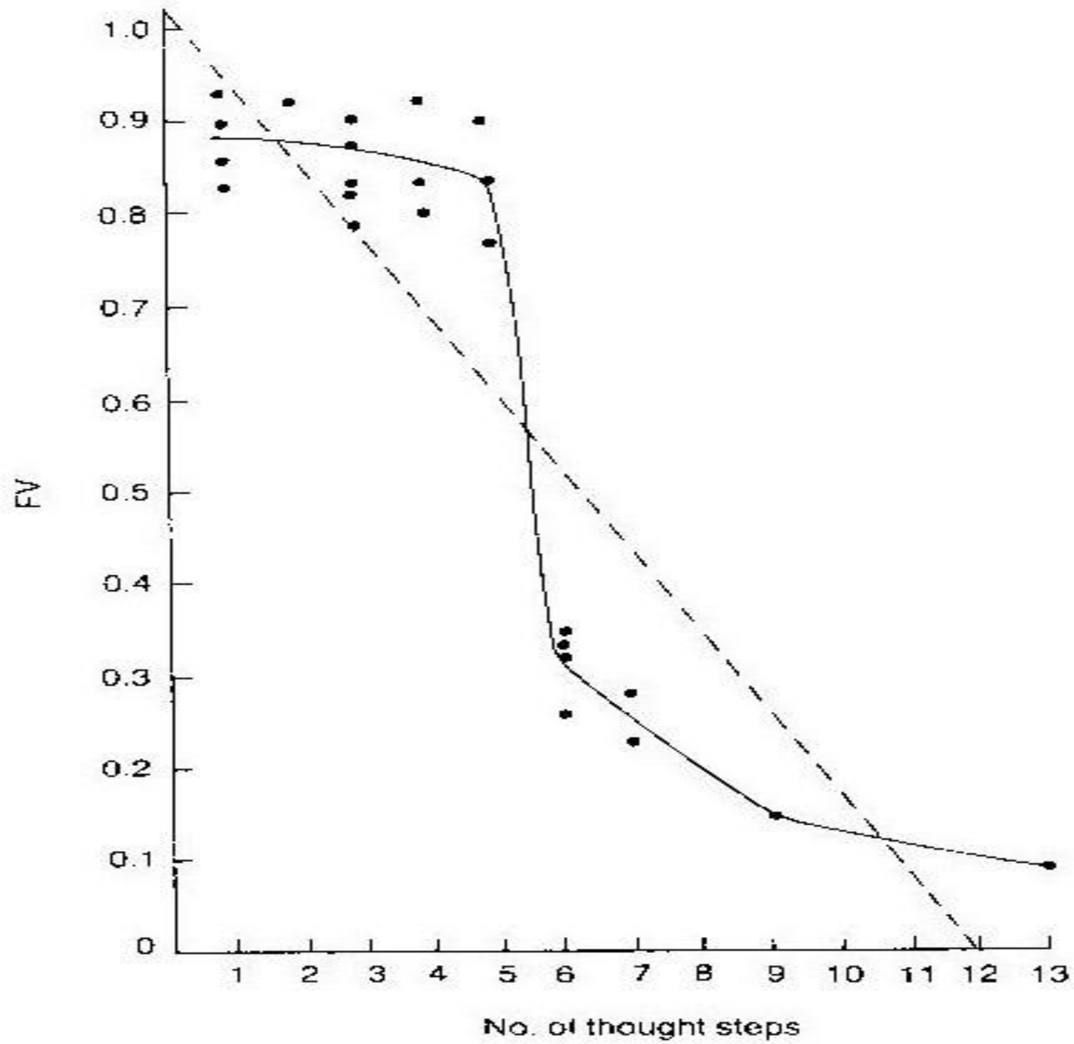
Have you used the triangle in your teaching?

Where might you introduce it?

Share you thoughts and ideas.

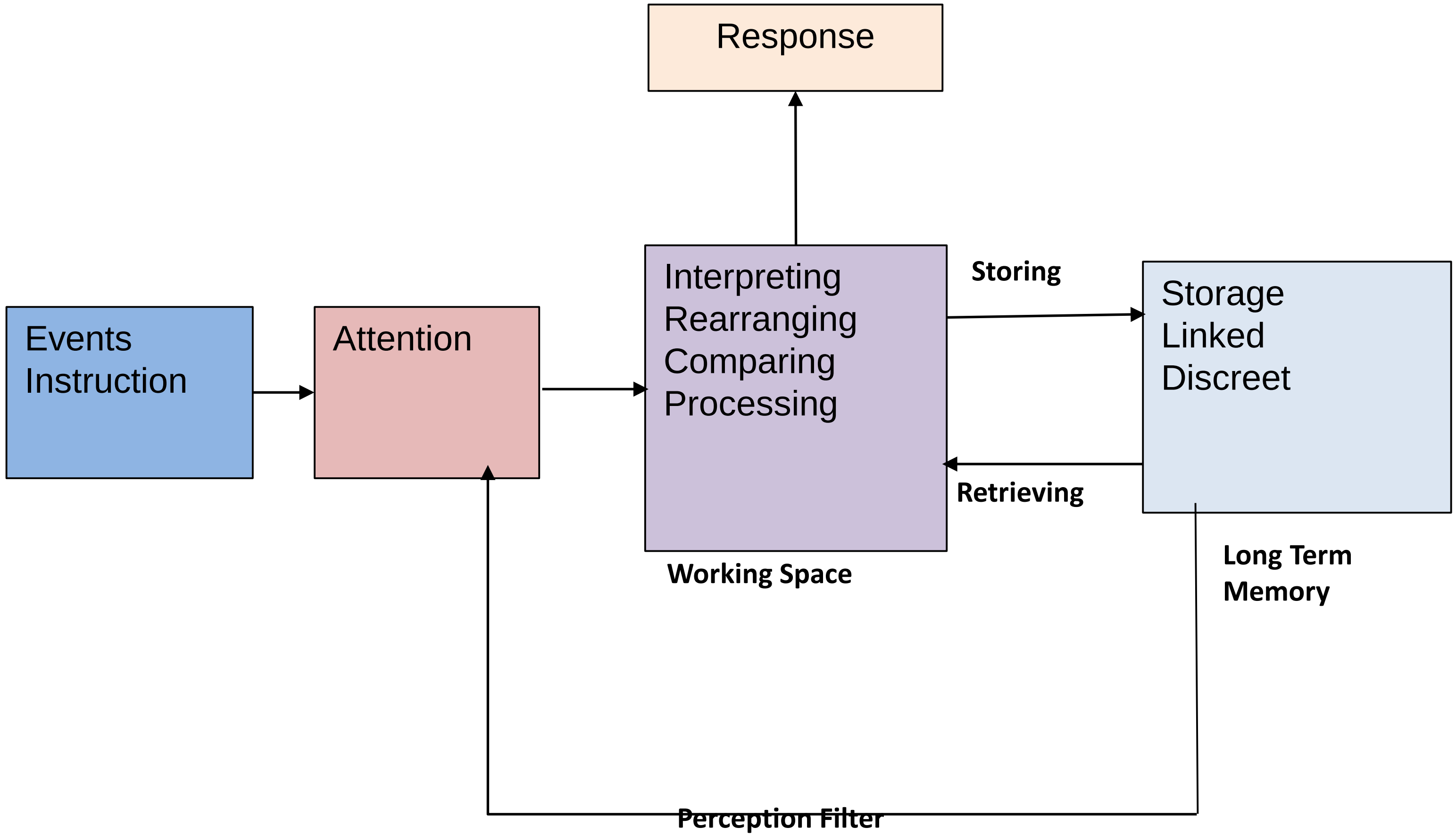
ALEX H JOHNSTONE

Cognitive load in learning Science



Information processing model

Miller, G.A., (1956), The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, 63, 81-97.



Johnstone's Ten Educational Commandments

1. What is learned is controlled by what you already know and understand.
2. How you learn is controlled by how you learned in the past (related to learning style but also to your interpretation of the "rules").
3. If learning is to be meaningful, it has to link on to existing knowledge and skills, enriching both (2).
4. The amount of material to be processed in unit time is limited (3).
5. Feedback and reassurance are necessary for comfortable learning, and assessment should be humane.
6. Cognisance should be taken of learning styles and motivation.
7. Students should consolidate their learning by asking themselves about what goes on in their own heads— metacognition.
8. There should be room for problem solving in its fullest sense (4).
9. There should be room to create, defend, try out, hypothesise.
10. There should be opportunity given to teach (you don't really learn until you teach) (5).

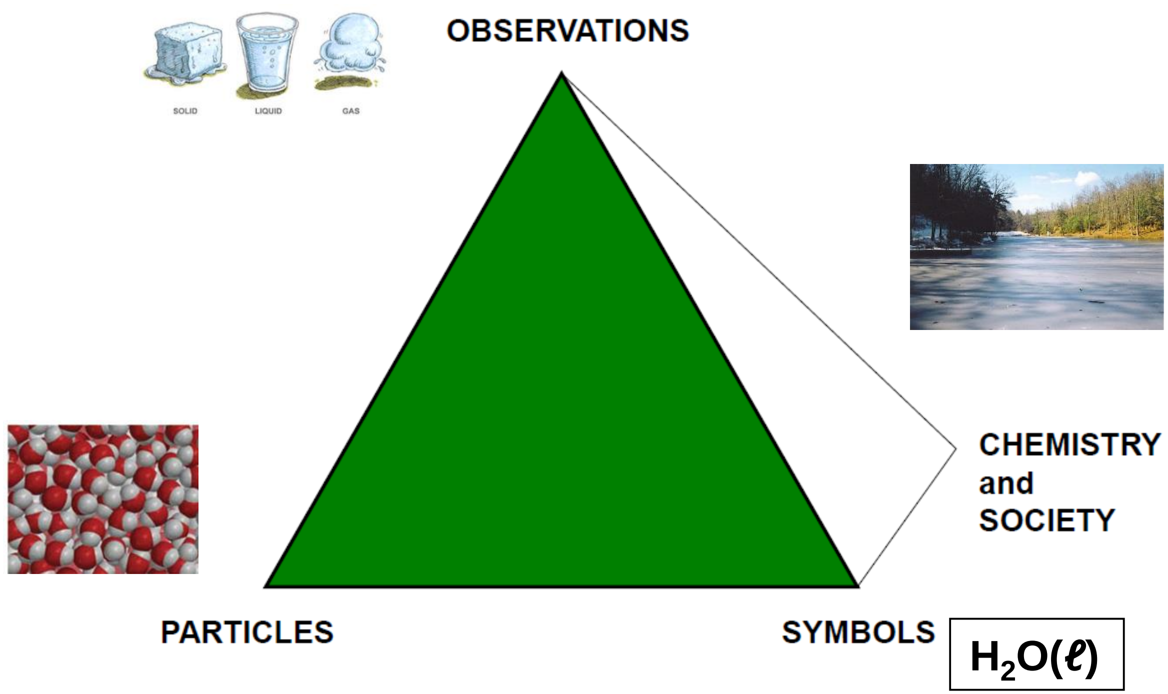
Johnstone said that they have been built into his own research and practice, using them as "stars to steer by".

IMPLICATIONS - COMMUNICATION

Understanding in chemistry is determined when we address chemical phenomena in the three dimensions by which they are demonstrated

- ***Macroscopic / observations*** : what can be seen touched and smelt
- ***Submicroscopic / particles*****:** atoms, molecules, ions
- ***Symbols*****:** formulae, equations, calculations and graphs

Chemical literacy is demonstrated through explanations that accurately link observations to the nature of the particles involved and represent these using chemical symbolism such as equations



IMPLICATIONS - COMMUNICATION

In your writing take care to differentiate between the macroscopic and the sub-microscopic levels.

Examples: Rewrite the following statements to accurately reflect the three levels of chemistry.

- C_6H_{14} is hexane

C_6H_{14} is the molecular formula for hexane, which is a colourless liquid

- Nylon is a long molecule

Nylon is not a long molecule although its molecules are long

- In an oxidation reaction zinc loses electrons

In an oxidation reaction zinc does not lose electrons but zinc atoms do

- Hydrogen is the smallest element

Hydrogen is not the smallest element, it is the element with the smallest atoms.

- Molecules of methane are non-polar so they have a low boiling point

Molecules can't have a boiling point but methane liquid is composed of lots of non-polar molecules so the liquid will have a low boiling point

- List all the forces of attraction between the molecules in their liquid state
- Write an equation to represent the enthalpy of fusion (melting), $\Delta_{fus}H°$,

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Examples: Rewrite the following statements to accurately reflect the three levels of chemistry.

- C_6H_{14} is hexane

Hexane is a colourless liquid. The composition of the molecules of hexane can be represented as C_6H_{14}.

- Nylon is a long molecule

Nylon is a fabric made of polymers which are very long molecules

- In an oxidation reaction zinc loses electrons

In an oxidation reaction the zinc atoms that make up the metal lose electrons

- Helium is the smallest element

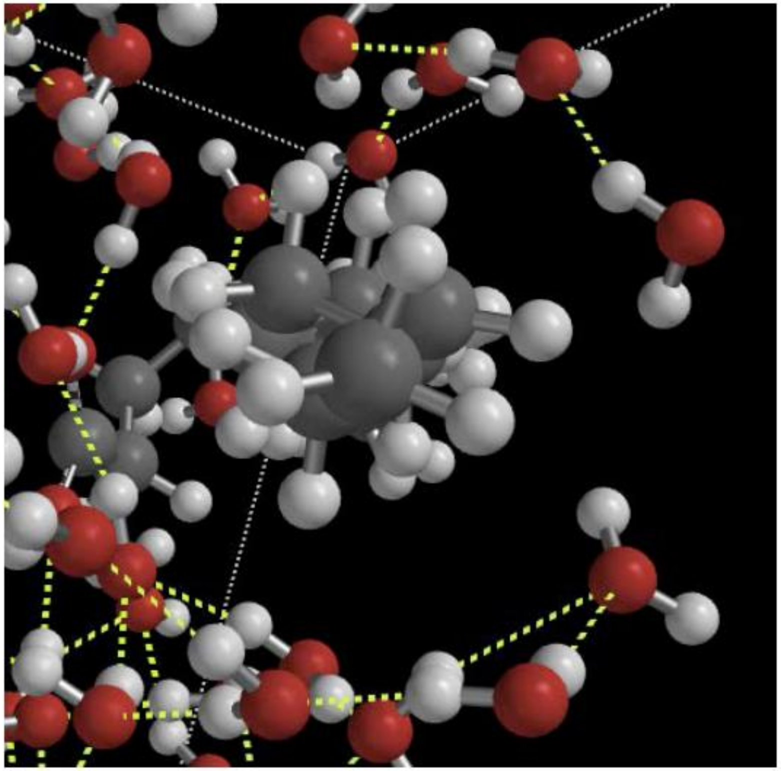
Helium is the element with the smallest atoms.

- Molecules of methane are non-polar so they have a low boiling point

Methane liquid is composed of non-polar molecules (with weak intermolecular attractions) so the liquid will have a low boiling point.

Note: Single molecules can’t have a boiling point!

THE CULT OF THE SINGLE MOLECULE



COMMUNICATION PRACTICE 1:

The following table provides information about 0.100 mol L^{-1} solutions of ammonia, ammonium nitrate and nitric acid. Use the three aspects of chemical thinking to give an account of the variation in the properties.

Compound	**Electrical Conductivity**	**pH**
NH_3	Slight	11.1
NH_4NO_3	Good	5.1
HNO_3	Good	1.0

For each set of observations, decide which particles/particle behaviour is responsible for the observation and the formulae/equations that link the particles and the observations.

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pH → Depends on $[H_3O^+]$ and $[OH^-]$ – need to know how 'particles' react with water – salt, acid or base, strong or weak

conductance → Depends on [ions] – Na^+, NH_4^+, NO_3^-, H_3O^+, OH^-
Also consider: salt, strong/weak acid or base

Equations:

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ (pH > 7, low conductivity since equm lies ← & [ions] low)

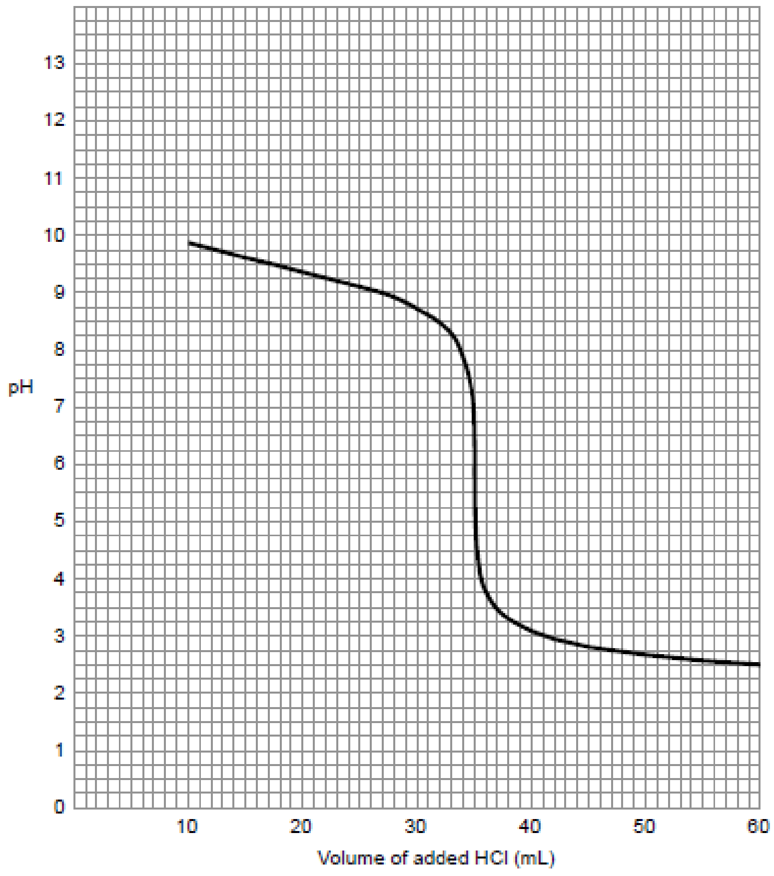
$NH_4NO_3 \rightarrow NH_4^+ + NO_3^-$ (high conductivity as salt completely ionises)

$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ (pH < 7)

$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$ (pH < 7 high conductivity and low pH since complete ionisation – compared to NH_4^+ which has higher pH from lower $[H_3O^+]$

COMMUNICATION PRACTICE 2:

The weak base ethanolamine, $HOCH_2CH_2NH_2$, can be titrated with HCl. The graph below plots the titration of 25.0 mL of a solution of ethanolamine with 0.0107 mol L^{-1} HCl. The portion of the curve from 0 to 10 mL has been left out.



Relate the change in pH and the shape of the titration curve to the change in the nature and concentration of the species in the flask as the titration is carried out.

Note that there is no instruction to include equations and formulas but to communicate in the language and conventions of chemistry this would be expected.