We lied to you

Lies taught in VCE Chemistry Units 3 and 4

James Kennedy (2016)

About the author

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Foreword

This book is a collection of lies we taught to our Year 12 Chemistry students in their graduation year.

The lies include well-meaning simplifications of the truth, mistakes in the textbook, and, in a few extreme cases, blatant falsehoods.

This book isn’t a criticism of the VCE Chemistry course at all. In fact, I just want to highlight the sheer complexity of Chemistry and the need to make sweeping generalisations at every level so it can be comprehensible to our students. This is a legitimate practice called *constructivism* in pedagogical circles. (Look that up.)

Rules taught as ‘true’ usually work 90% of the time in this subject. Chemistry has rules, exceptions, exceptions to exceptions and so on. You’ll peel pack these layers of rules and exceptions like an onion until you reach the core, where you’ll find Physics and Specialist Maths.

Before you read this book, check out the University of Cambridge Chemistry Data Book here:

http://www.cie.org.uk/images/164870-2016-specimen-data-booklet.pdf

How many pages can you understand?

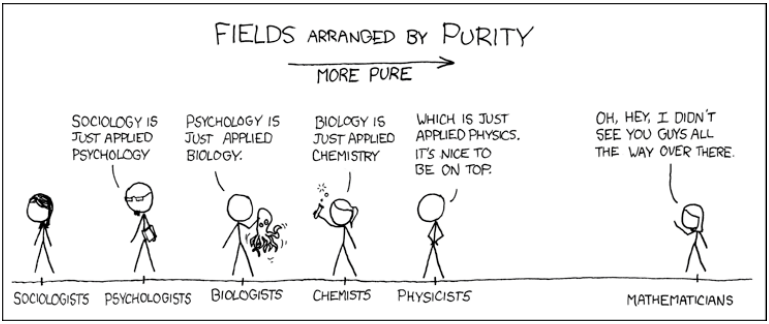
I just want you to know where Chemistry's headed.

The content you're learning now is probably not as true as it seems. Chemistry is a set of *models* that explain the macro level sometimes at the expense of detail. The more you study Chemistry, the more precise these models become, and they'll gradually enlighten you with a newfound clarity about the inner workings of our universe. It's profound.

Enjoy this book. I hope it emboldens you to question everything you're told, and encourages you to read *beyond* the courses you're taught in school.

Let's go!

Contents



Cartoon from xkcd.com

Part One: Lies taught in Year 12

LIE #1. IR Spectroscopy is qualitative

Infra-red spectroscopy is taught as a “qualitative technique”. However, there’s actually a quantitative use for it: in breathalysers, a filter wheel selects an infra-red beam of light with a wavenumber 3200-3550 cm^{-1}, which corresponds with the region of the electromagnetic spectrum where O-H (alcohol) absorption takes place. Light passes through the sample and is detected at the photocell, which, with the help of a microprocessor, puts a blood alcohol concentration (BAC) value on the screen.

In this instance, where IR spectroscopy is used to find the amount of O-H (alcohol) absorption on a person’s breath, it is a **quantitative** technique!

LIE #2. Density of water = 1.00 g mL^{-1} @ 25 °C

Incorrect. The density of water is 0.997044 g mL^{-1} at 25 °C, which, when rounded to 3 significant figures as it is in the 2016 Data Book, becomes 0.997 g mL^{-1}.

LIE #3. PV=nRT

The ideal gas formula (PV=nRT) relies on several assumptions we learned in Year 11:

- Random motion of particles
  What about wind?
- Negligible volume of particles
  Particles definitely have a non-zero volume
- Exert no forces on each other
  But what about dispersion forces?
- Collide elastically with each other and with the walls of the container
  Collisions often generate heat e.g. bicycle pump
- Kinetic energy is proportional to temperature
  Finally… that one is pretty much true!

You can see that most of these assumptions are not true. The formula we'd need if we were to take all of these truths into account would be:

$$\left(p + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

Calculating the values of a and b is tricky, too.

Here are the formulae for those constants, a and b:

$$a = \frac{27}{64} \times \frac{R^2 T_c^2}{P_c}$$

$$b = \frac{RT_c}{8P_c}$$

The overall equation, instead of PV=nRT, is actually:

$$\left(p + \frac{n^2 \frac{27}{64} \times \frac{R^2 T_c^2}{P_c}}{V^2}\right)\left(V - n\frac{RT_c}{8P_c}\right) = nRT$$

Does this even matter?

Yes! Using the simplified version of the formula (PV=nRT) can result in huge errors, sometimes giving answers 5× different from the experimentally-observed values!

PV=nRT is sometimes accurate. At other times, it gives you just a ballpark figure.

LIE #4. Some things are insoluble

Solubility is a continuum that's measured by a value called a solubility product, or "K_{sp}".

You can make a K_{sp} expression in a very similar fashion to how you'd make a K_a expression.

For example:

Barium sulfate is "insoluble" in water.

$$BaSO_4(s) \leftrightarrow Ba^{2+}(aq) + SO_4^{2-}(aq)$$

$$K_{sp} = 1.1\times10^{-10}$$

This is a very low K_{sp} value, meaning that $BaSO_4$ has extremely low solubility in water.

Ice tables show exactly how much $BaSO_4$ dissolves in water. One gram of $BaSO_4$ in one litre of water would result in a concentration of 0.00001054 M $BaSO_4(aq)$ in the water.

This is small, but it's not zero.

Insoluble doesn't mean that *zero* dissolves.

LIE #5. Indicators are a good idea

Not really. pH meters give a much more accurate reading of pH than judging the colour of an indicator by eye. There are even automated titration machines for sale online that use pH meter instead of an indicator. Indicators have colour changes that are too broad or difficult to see, which causes errors when judging the end point.

LIE #6. An acid is a proton donor

Wrong again! An acid was only defined as a proton donor by Brønsted and Lowry in 1923. Many other definitions exist that are still in use.

Here are some:

Theory	Year	Definition of 'acid'
Liebig	1838	hydrogen-containing substance
Arrheinus	1884	produce $H^+(aq)$ in solution
Brønsted-Lowry	1923	donates $H^+(aq)$ in solution
Lewis	1923	accepts a pair of electrons
Usanovich	1938	accepts negative species
Lux-Flood	1947	an O^{2-} acceptor

LIE #7. That direct titration of ammonia solution was a good idea

No way. We did this, though, at the beginning of the year. Ammonia, $NH_3(aq)$, is a weak base and needs to be back-titrated. Direct titration of a weak base, which is what we did, doesn't give a clear end point.

LIE #8. KOHES is the way to balance half equations

KOHES only works for cells with acidic electrolytes. For cells with alkaline electrolytes, which sometimes appear in VCAA papers despite not being in the study design, you'll need to use KOHES(OH).

Here's KOHES(OH) explained:

1. Do KOHES as normal

2. Add the same number of $OH^-(aq)$ ions to each side of the half-equation to balance out the $H^+(aq)$

3. Cancel and simplify. Remember that $H^+(aq) + OH^-(aq)$ makes $H_2O(l)$.

4. Remember also to cancel out any $H_2O(l)$.

LIE #9. Peak height on a chromatogram represents the concentration of component in a sample

Wrong again. It’s actually the area under each peak that represents the amount of component coming out of a chromatography column. VCAA just changed this to ‘height’ to make it easier to measure using a rules in examinations.

The same goes for NMR spectra. You might have noticed that genuine low-resolution NMR spectra can have peaks due to 2 H that are *taller* than the peaks due to 3 H. Again, it’s area under each peak that matters, not peak height.

VCAA draws spectra by hand so this phenomenon never occurs in VCE questions!

LIE #10. Phenolphthalein is ‘red’ at high pH

Does that look red to you?

It’s *magenta*!

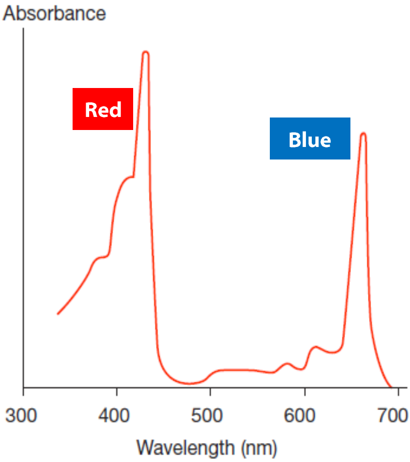
LIE #11. The colour wheel is a useful concept

I try to avoid mentioning the colour wheel when teaching spectroscopy even though it's mentioned in so many textbooks and worksheets.

The misconception here is that objects with a particular colour absorb the complementary colour on the other side of the colour wheel.

We just need to look at leaves to see this isn't true. Leaves are light green – and according to the colour wheel, they should be absorbing purple light. In reality, they absorb two colours: red and blue, but not purple.

Here's the absorption profile for chlorophyll:



LIE #12. We need to be able to interpret IR & NMR spectra accurately

Not unless you're a trained expert. Most scientists just send their samples off to the experts for analysis. Even if you're using the machine yourself, modern spectrometers are linked to internet databases, and automatically interpret the spectra for you! They even tell you the name of the compound.

LIE #13. All fragment ions formed in a mass spectrometer will have a + charge

Usually, yes. However, sometimes, a fragment will become ionised with a 2+ charge as two electrons are knocked out of the molecule. This produces a set of superimposed 'shadow' peaks with half the m/z values of the originals. VCAA doesn't tell you this.

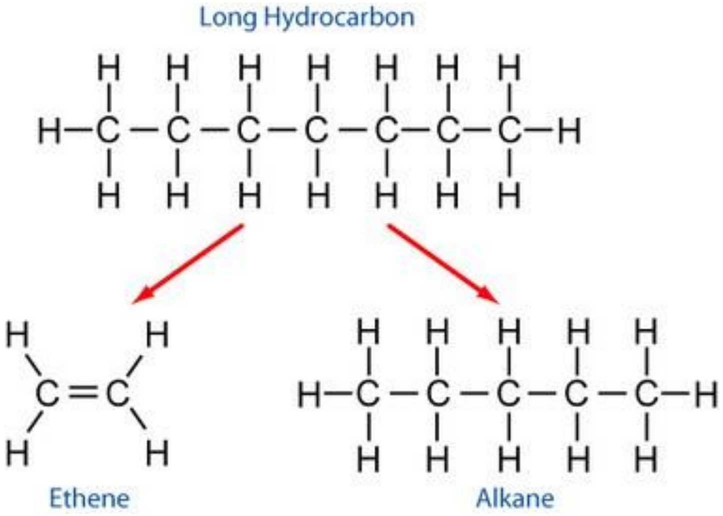
LIE #14. There are two reactions of alkanes: combustion and substitution

There's a third one: **cracking**.

Cracking is a reaction in which a long alkane is converted into one smaller alkane and one very small alkene, usually ethene.

Zeolite catalysts and a temperature of 500 °C are required.

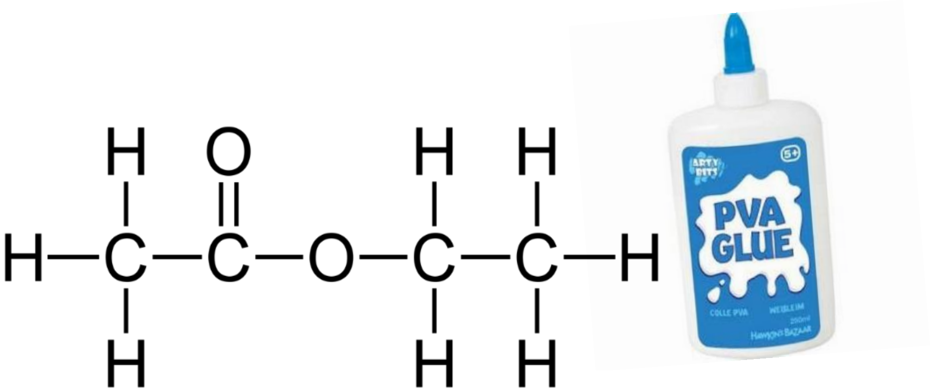
It's a very useful reaction in the petroleum industry and is taught in most curricula – but not in VCE.



LIE #15. Ethyl ethanoate smells fruity

Most esters smell fruity but ethyl ethanoate is probably the least pleasant-smelling of all. Organoleptic* analyses report ethyl ethanoate as smelling like a “glue stick”. Not fruity at all.

**look it up.*



LIE #16. E10 petrol contains 10% ethanol

No. E10 petrol sold in Australia can contain *up to* 10% ethanol by volume. Producers whose fuel exceeds the 10% threshold face hefty fines.

LIE #17. Bioethanol is carbon neutral

No! If the processes of tilling, planting, growth, farming, fertilisation, irrigation, harvesting, transportation, fermentation and distribution were all 100% efficient, then bioethanol would be carbon neutral. But it's not. For a start, only around 10% of the carbon content in the plant actually gets converted into ethanol. The rest, which is mostly cellulose, hemicellulose and lignin, can't be digested by the enzymes used in the fermentation process and get wasted or burned off instead. Per life cycle, bioethanol emits almost as much CO_2 as fossil fuels.

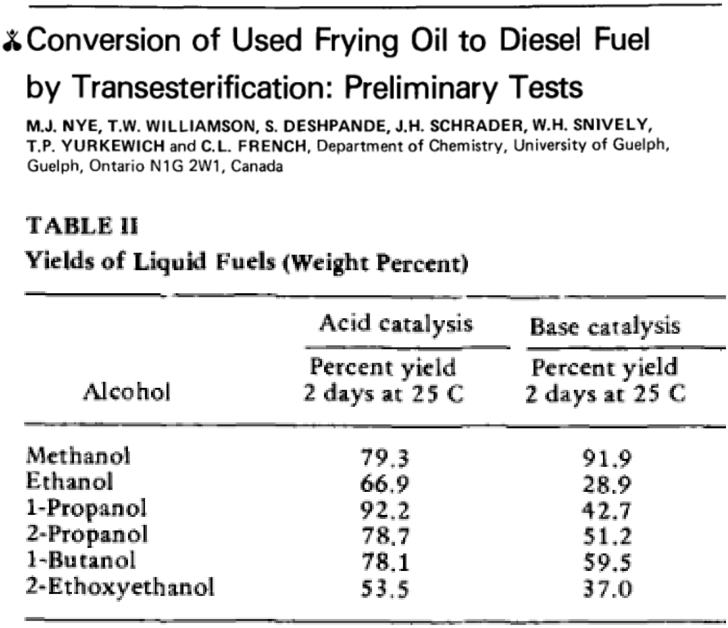
LIE #18. The semi-structural formula of oleic acid is $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$

Unless it's an omega-3/6/9 fatty acid, it doesn't really matter where the carbon-carbon double bond is located. Structural isomers of oleic acid where the carbon-carbon double bond is located at a different carbon atom are still called 'oleic acid'.

LIE #19. Transesterification of triglycerides to biodiesel requires an $OH^-(aq)$ catalyst

Wrong. In fact, acid (H^+) catalysts sometimes work **better** and it's a shame that VCAA doesn't agree.

Here's proof:



Conversion of Used Frying Oil to Diesel Fuel by Transesterification: Preliminary Tests

M.J. NYE, T.W. WILLIAMSON, S. DESHPANDE, J.H. SCHRADER, W.H. SNIVELY, T.P. YURKEWICH and C.L. FRENCH, Department of Chemistry, University of Guelph, Guelph, Ontario N1G 2W1, Canada

TABLE II
Yields of Liquid Fuels (Weight Percent)

Alcohol	Acid catalysis Percent yield 2 days at 25 C	Base catalysis Percent yield 2 days at 25 C
Methanol	79.3	91.9
Ethanol	66.9	28.9
1-Propanol	92.2	42.7
2-Propanol	78.7	51.2
1-Butanol	78.1	59.5
2-Ethoxyethanol	53.5	37.0

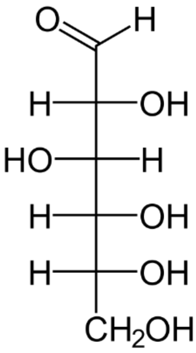
Reference: Nye, M. J. et al. "Conversion Of Used Frying Oil To Diesel Fuel By Transesterification: Preliminary Tests". *Journal of the American Oil Chemists' Society* 60.8 (1983): 1598-1601. Web.

There exist enzymes that catalyse this reaction but this method is not economically viable.

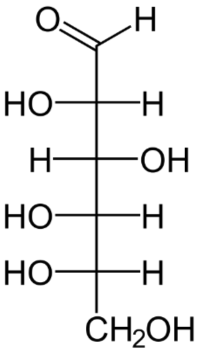
LIE #20. The structural formula of glucose in the Data Book is correct

Glucose *mutarotates* between its many isomers.

First, there are two **stereoisomers** called L- and D-glucose. D-glucose is found widely in living things while L-glucose is not.



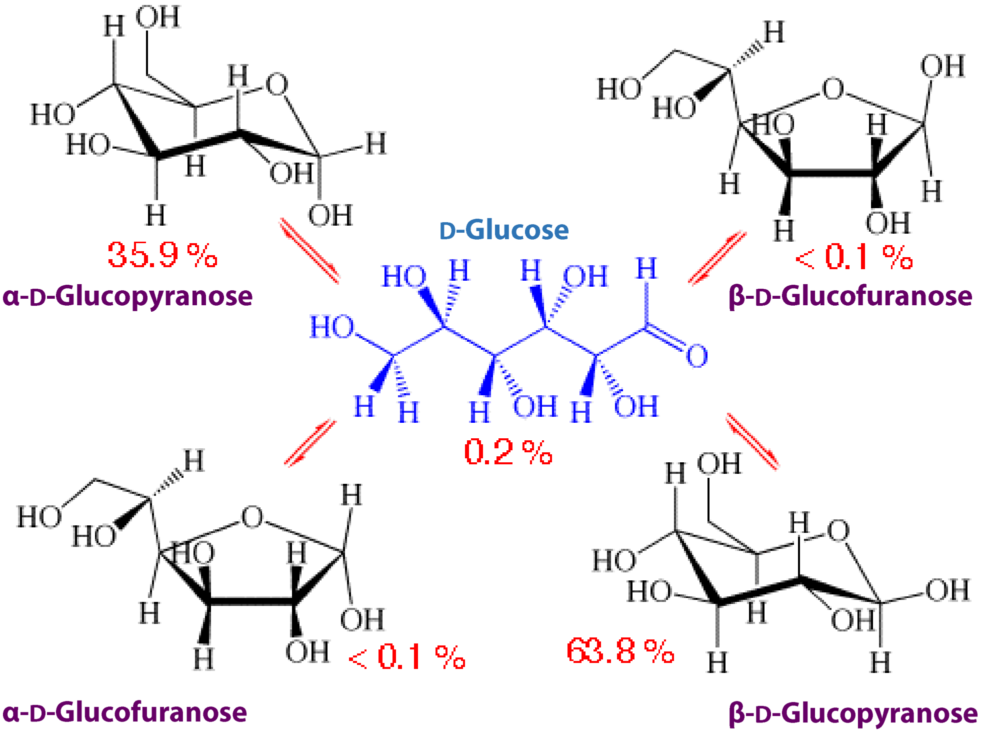
D-Glucose



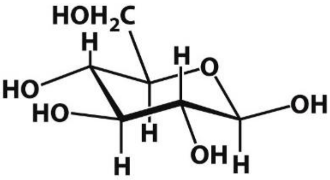
L-Glucose

L-glucose tastes exactly the same as D-glucose but cannot undergo glycolysis because the first enzyme (hexokinase) can't bind to it. The L-glucose stereoisomer is therefore a healthy, zero-calorie sweetener that tastes *exactly* like real sugar. It's also been shown to stimulate the release of insulin, and has been used as medication for diabetes mellitus.

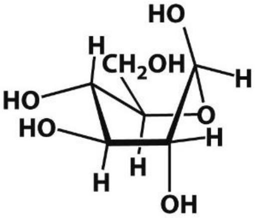
Second, you'll notice that both molecules were drawn *straight* above. Less than 1% of glucose exists as the straight ("open") isomer in aqueous solution. The straight glucose molecule reacts with itself to form several **cyclic isomers**, each of which is chiral:



Third, each of the glucopyranose cyclic isomers on the previous page can exist in one of two stable **confomers** called ‘boat’ and ‘chair’.



Chair form



Boat form

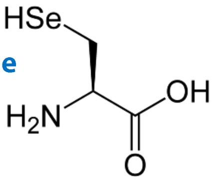
Finally, each isomer of glucose is subject to **rotational isomerism**. Rotation may occur around the O6-C6-C5-O5 torsion angle, termed the ω-angle, to form three staggered rotamer conformations called *gauche-gauche* (gg), *gauche-trans* (gt) and *trans-gauche* (tg).

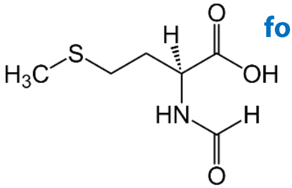
Overall, linear glucose can twist, turn and react with itself to form 7×2×3=42 different forms.

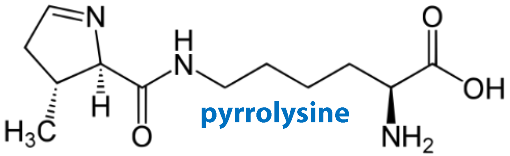
This figure of course excludes the many structural isomers of glucose that exist, including fructose and galactose. These, too, have more than one form in aqueous solution.

LIE #21. There are 20 amino acids

There are 20 amino acids that can be encoded by DNA codons. There are an additional 3 amino acids (formylmethionine, selenocysteine and pyrrolysine) that are formed **naturally** in our cells via post-translational modification.


selenocysteine


formylmethionine

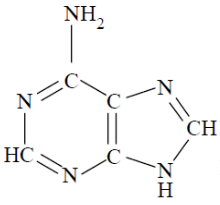

pyrrolysine

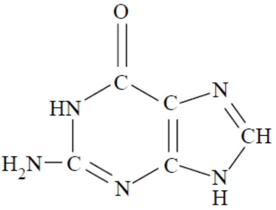
In addition to these, there are about 900 naturally-occurring amino acids in various organisms, and another 120 artificial ones have been successfully incorporated into proteins.

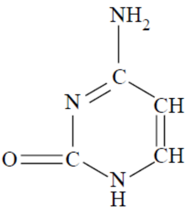
There are also twin-amino acid stereocentres, and D-amino acids, which are stereoisomers of the ‘normal’ L-amino acids. There are well over 1000 amino acids.

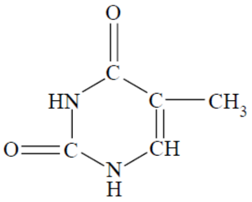
LIE #22. There are 4 nucleotides in DNA

The Data Book tells us there are four nucleotides.

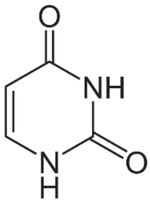

adenine


guanine

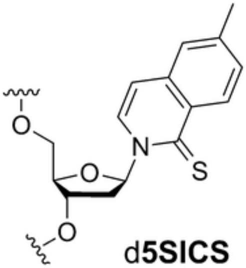

cytosine

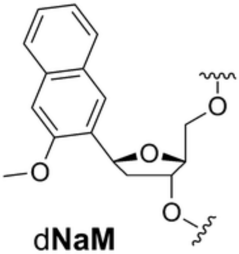

thymine

There’s also uracil, which is present in RNA, not DNA.



Then, there are the two artificial DNA nucleotides created in 2012 called d5SICS and dNaM.


d5SICS


dNaM

LIE #23. There are three levels of structure in proteins

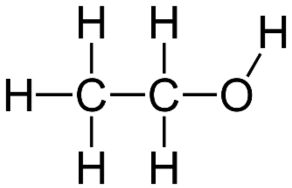
There's a fourth level called *quaternary structure* as well. VCE Biology students know this well—it's the combination of a small number of subunits to make a larger protein complex.

LIE #24. Denaturing enzymes alters their tertiary structure only (page 196)

Wrong. Both secondary and tertiary structure are disrupted. The textbook says that only tertiary structure is disrupted when enzymes are denatured.

LIE #25. Hydroxyl groups are neutral

Pure ethanol has a pH of 7.33. Hydroxyl groups are actually *very slightly* basic.



LIE #26. Increasing reactant concentration always increases rate of reaction

Reaction rate is quite complex. Some reactions are what’s known as *zero order*, which means that rate is independent of reactant concentration.

Enzyme-catalysed reactions tend to be zero order because the reaction rate is limited by the concentration of *enzyme*, not by the concentration of reactants. In such cases, increasing reactant concentration has no effect on reaction rate!

LIE #27. Atom economy is important

Not really. By chasing atom economy, an industry might have less *mass* of waste, but the waste might be more harmful than from the conventional process.

For example, atom economy calculations persuade scientists to replace chlorine atoms with fluorine atoms just because they’re lighter—even though they’re much more dangerous for living things.

LIE #28. You can change pressure while keeping temperature constant

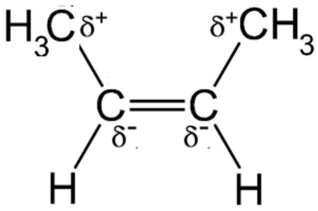
No. Think about a bicycle pump: when you inflate the tyre, pressure inside the pump and tyre is increased. This causes an increase in temperature.

When compressed gas (for example, $CO_2(g)$ in a fire extinguisher) is decompressed, heat is absorbed and the temperature increases. Pressure is not completely independent of temperature.

LIE #29. Alkenes are non-polar

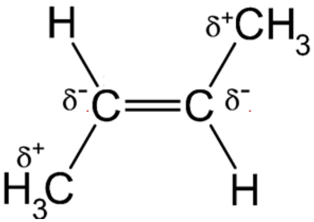
Many alkenes have a tiny net dipole that we ignore at VCE level. Propene has a net dipole of 0.366 D due to its asymmetrical shape, and *cis*-but-2-ene is more polar than *trans*-but-2-ene for the same reason.

***cis*-but-2-ene**
Slightly more polar



BP = 4°C

***trans*-but-2-ene**
Slightly less polar



BP = 1°C

LIE #30. Concentration of weak acid remains unchanged during ionisation

Sometimes, it changes significantly. For example, in a 0.001 M solution of propanoic acid, 11.6% of the acid molecules have ionised:

$$\%\ \text{ionisation} = \sqrt{\frac{K_a}{[\text{acid}]}} \times 100$$

$$\%\ \text{ionisation} = \sqrt{\frac{1.34\times10^{-5}}{0.001}} \times 100$$

$$\%\ \text{ionisation} = 11.6\%$$

In this example, the concentration of the acid has changed by 11.6%! In other words, it's no longer actually 0.001 M. It should be significantly less.

The correct way to calculate pH of weak acids is to make an ice table… but VCAA refrains from asking such questions in the current study design.

LIE #31. The electrochemical series is accurate

It serves as a good approximation voltage between two half cells but has two major limitations that we don't talk about at VCE level.

First, it only works at standard conditions. To find E^0 at non-standard conditions, we need to use the Nernst equation:

$$E_{red} = E^{\ominus}_{red} + \frac{\mathrm{RT}}{\mathrm{zF}} \times \ln\left(\frac{a_{ox}}{a_{ox}}\right)$$

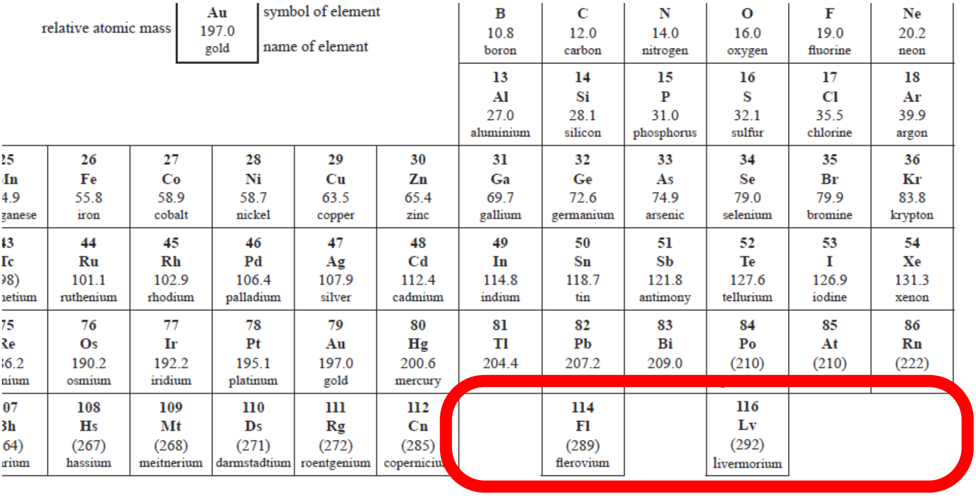
Second, there's **overpotential**, which is essentially the error between the value predicted by the Nernst equation and the value measured experimentally. There are different types of overpotential: activation overpotential and concentration overpotential.

The discrepancy between the electrochemical series and the actual voltage obtained can be as large as one volt!

LIE #32. The periodic table in the 2016 Data Book is accurate

Take a closer look. Four elements are missing.

Several months before the 2016 Data Book was released, the IUPAC confirmed four new elements (nihonium, moscovium, tennessine, and oganesson) in the 7th row of the *p* block. They're missing in the 2016 Data Book!

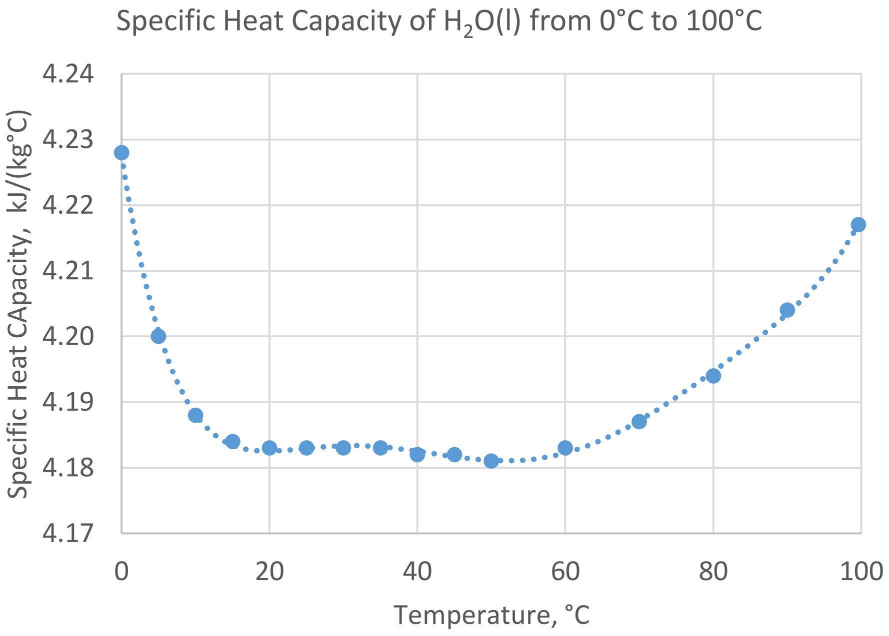


	relative atomic mass	Au 197.0 gold	symbol of element name of element			B 10.8 boron	C 12.0 carbon	N 14.0 nitrogen	O 16.0 oxygen	F 19.0 fluorine	Ne 20.2 neon
						13 Al 27.0 aluminium	14 Si 28.1 silicon	15 P 31.0 phosphorus	16 S 32.1 sulfur	17 Cl 35.5 chlorine	18 Ar 39.9 argon
5 n 4.9 ganese	26 Fe 55.8 iron	27 Co 58.9 cobalt	28 Ni 58.7 nickel	29 Cu 63.5 copper	30 Zn 65.4 zinc	31 Ga 69.7 gallium	32 Ge 72.6 germanium	33 As 74.9 arsenic	34 Se 79.0 selenium	35 Br 79.9 bromine	36 Kr 83.8 krypton
3 c 8) etium	44 Ru 101.1 ruthenium	45 Rh 102.9 rhodium	46 Pd 106.4 palladium	47 Ag 107.9 silver	48 Cd 112.4 cadmium	49 In 114.8 indium	50 Sn 118.7 tin	51 Sb 121.8 antimony	52 Te 127.6 tellurium	53 I 126.9 iodine	54 Xe 131.3 xenon
5 e 6.2 nium	76 Os 190.2 osmium	77 Ir 192.2 iridium	78 Pt 195.1 platinum	79 Au 197.0 gold	80 Hg 200.6 mercury	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (210)	85 At (210)	86 Rn (222)
07 h 64) rium	108 Hs (267) hassium	109 Mt (268) meitnerium	110 Ds (271) darmstadtium	111 Rg (272) roentgenium	112 Cn (285) coperniciu		114 Fl (289) flerovium		116 Lv (292) livermorium		

LIE #33. The specific heat capacity (c) of water is 4.18 J g^{-1} K^{-1}

The specific heat capacity of liquid water varies with temperature. In other words, as water heats up above about 50 °C, the hydrogen bonds between water molecules become slightly more difficult to break.

The specific heat capacity of water is *not constant*.



Part Two: Lies taught in Year 11

LIE #34. Significant figures

This is one of my favourites.

Some students obsess over significant figures even though they're only worth one mark in the exam.

Other students ignore them completely and write down all the digits on the calculator display, which infuriates examiners and loses marks.

The rule taught at VCE level that *"the answer is only accurate to the minimum number of significant figures used in the calculation"* is only true for multiplication and division operations.

Addition operations are as accurate as the minimum number of decimal places in the input values.

When taking **logarithms**, the number of significant figures in the original value becomes the number of decimal places in the result.

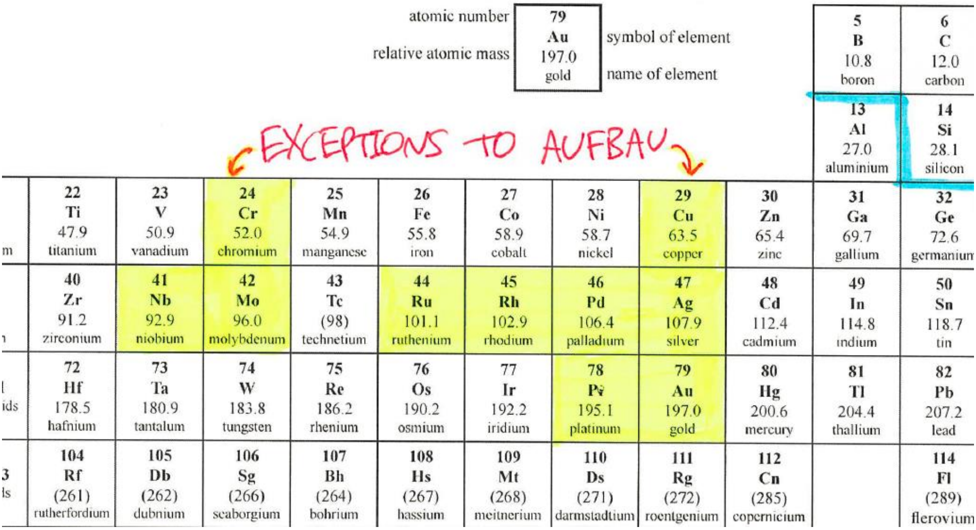
For example:

The pH of $\underline{1.23}$ M $HCl(aq)$ is $-0.\underline{090}$.
The $[H^+]$ of pH $3.\underline{25}$ solution is $\underline{5.6}\times10^{-4}$ M

LIE #35. Aufbau principle works

There are two exceptions to the aufbau principle (copper and chromium) between hydrogen (Z=1) and krypton (Z=36). Exceptions to the rule become increasingly numerous after krypton.

About a quarter of the d-block and a quarter of the f-block don't follow the aufbau rule. Examples include niobium, technetium, silver, gold and palladium. The reason for the deviation from the aufbau rule is the that the energy levels of subshells varies in complex ways as those subshells are progressively filled.



atomic number / relative atomic mass — 79 Au 197.0 gold — symbol of element / name of element

EXCEPTIONS TO AUFBAU

											5 B 10.8 boron	6 C 12.0 carbon
											13 Al 27.0 aluminium	14 Si 28.1 silicon
m	22 Ti 47.9 titanium	23 V 50.9 vanadium	24 Cr 52.0 chromium	25 Mn 54.9 manganese	26 Fe 55.8 iron	27 Co 58.9 cobalt	28 Ni 58.7 nickel	29 Cu 63.5 copper	30 Zn 65.4 zinc	31 Ga 69.7 gallium	32 Ge 72.6 germanium
1	40 Zr 91.2 zirconium	41 Nb 92.9 niobium	42 Mo 96.0 molybdenum	43 Tc (98) technetium	44 Ru 101.1 ruthenium	45 Rh 102.9 rhodium	46 Pd 106.4 palladium	47 Ag 107.9 silver	48 Cd 112.4 cadmium	49 In 114.8 indium	50 Sn 118.7 tin
l ids	72 Hf 178.5 hafnium	73 Ta 180.9 tantalum	74 W 183.8 tungsten	75 Re 186.2 rhenium	76 Os 190.2 osmium	77 Ir 192.2 iridium	78 Pt 195.1 platinum	79 Au 197.0 gold	80 Hg 200.6 mercury	81 Tl 204.4 thallium	82 Pb 207.2 lead
3 ls	104 Rf (261) rutherfordium	105 Db (262) dubnium	106 Sg (266) seaborgium	107 Bh (264) bohrium	108 Hs (267) hassium	109 Mt (268) meitnerium	110 Ds (271) darmstadtium	111 Rg (272) roentgenium	112 Cn (285) copernicium		114 Fl (289) flerovium

LIE #36. $3d^9$ is unstable

Not always true. While $3d^9$ is unstable in elemental copper, giving rise to its unusual electron configuration, it's important to know that there's an exception to the *exception*: that's the copper(I) ion.

Electron configuration of Cu^+ is [Ar] $3d^9$ $4s^1$

In full, that's $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $3d^9$ $4s^1$

LIE #37. Noble gases don't react

Chemistry is far more complex than we teach at VCE level. Most noble gases form exotic compounds.

Helium forms $He(N_2)_{11}$ ("helium-nitrogen crystals") at extreme pressures above 100,000 atmospheres.

Argon forms HArF (argon fluorohydride) at very low temperatures (below 10 K).

Xenon forms XeF_4 (xenon tetrafluoride) under extreme conditions to form a gas that's heavier than air and is safe to breathe. Steve Spangler used it on TV to make his voice deeper (watch it on YouTube) .

LIE #38. There are three states of matter

There are four fundamental states of matter: solid, liquid, gas and plasma. Plasma is formed when a gas is heated to a high enough temperature that the electrons become delocalised from the atoms they usually orbit. Examples include lightning, neon lights, electric sparks and plasma televisions.

There are at least additional **15 states of matter** including superfluids, Bose-Einstein condensates and glass. Read more about them all here.

LIE #39. Protons and neutrons have equal mass

Not exactly. Protons have mass $1.6726219 \times 10^{-27}$ kg, and neutrons have mass $1.674929 \text{ x } 10^{-27}$ kg. There's a difference of 0.138%, which we ignore at VCE level.

LIE #40. Electrons have no mass

VCE physics students know that electrons have small but significant mass. It's $9.10938356 \times 10^{-31}$ kg.

LIE #41. Mercury, Hg, is the only liquid metal at room temperature

Three metals are liquid at ‘room’ temperature.

Mercury is the most common liquid metal.

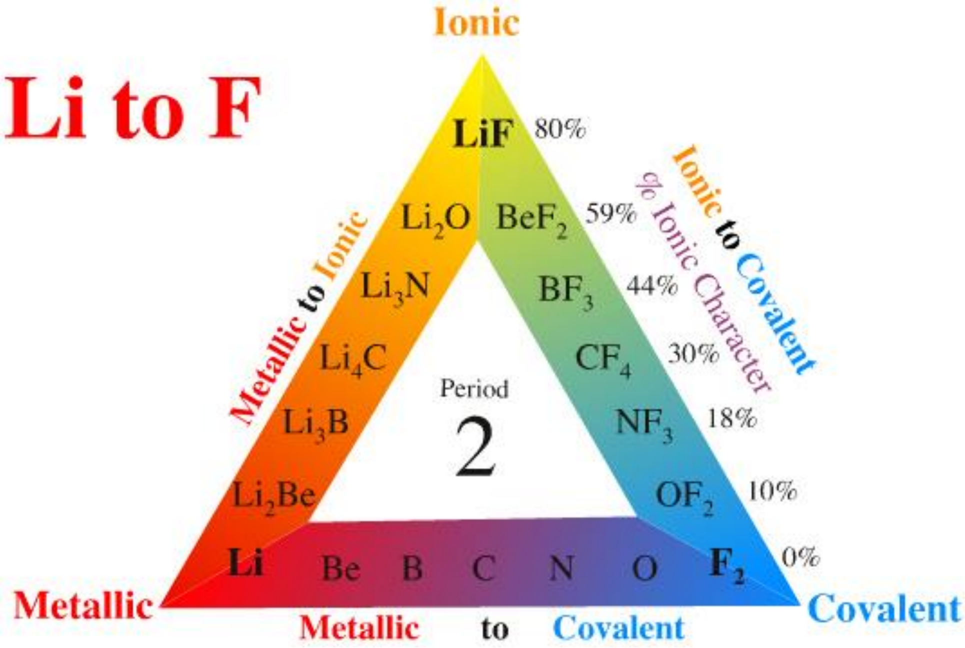
NaK is a little-known alloy of sodium and potassium. When these two metals are melted together, they cool to form an alloy that’s liquid at room temperature. Its low melting point and high electrical conductivity makes it an excellent coolant in the latest fast neutron nuclear reactors.

Gallium melts at 36 °C, which is about the same as chocolate. You can buy spoons made from gallium that look perfectly normal until you put them into lukewarm water. The spoon melts!

A gallium teaspoon melting in lukewarm water

LIE #42. Ionic, covalent and metallic are three distinct types of bonding

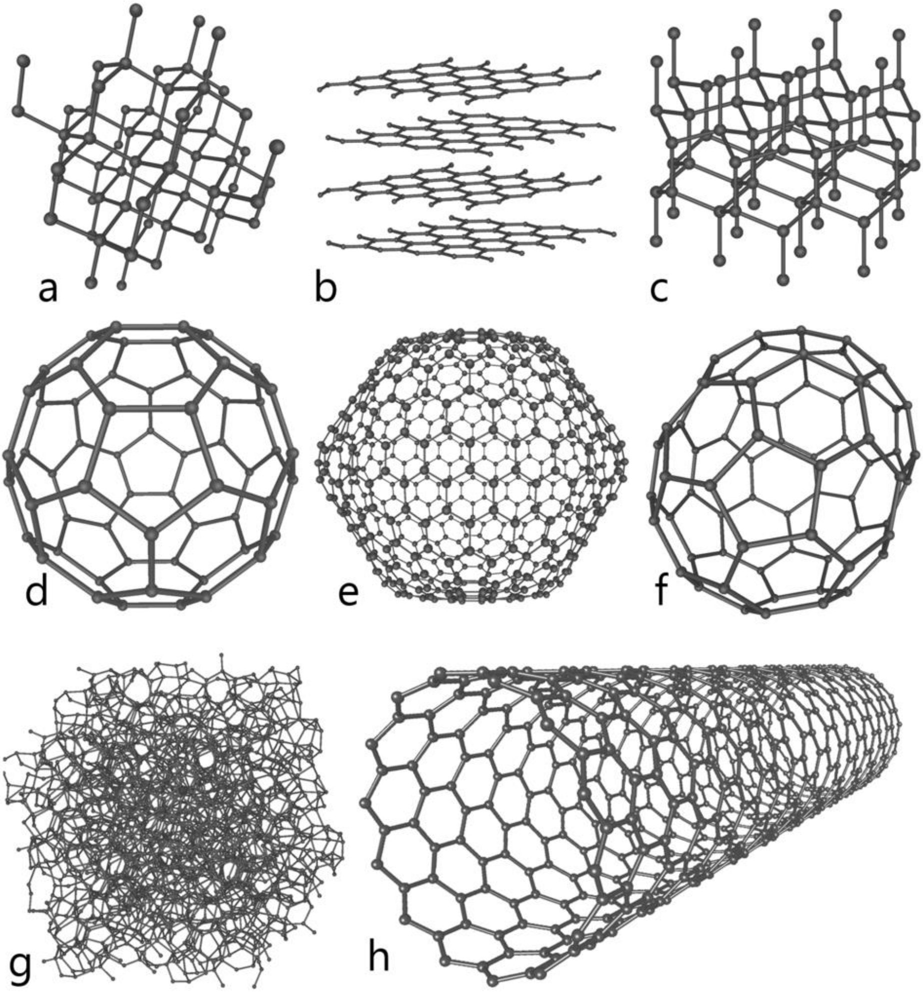
Bonding types actually on a spectrum called a **van Arkel triangle** shown below.



Carbon is an interesting example. Carbon is found in the middle of ‘metallic’ and ‘covalent’ on the bottom of the chart; and as such, has intermediate properties. Like a metallic substance, it has a high melting point and conducts electricity. Like a covalent substance, it’s soft and dull.

LIE #43. There are only three different forms (allotropes) of carbon

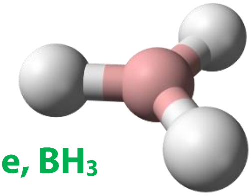
There are at least 10 allotropes of carbon. Eight of them are depicted below.



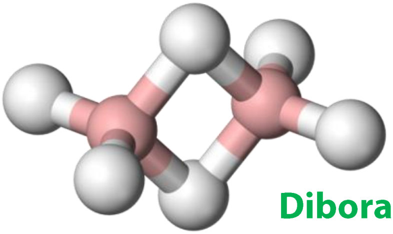
LIE #44. BH_3 is stable

The textbook implies that BH_3 is a stable compound even though it doesn't obey the octet rule. BH_3 is in fact very unstable and tends to dimerise and trimerise to become B_2H_6 and B_3H_9 and so on.

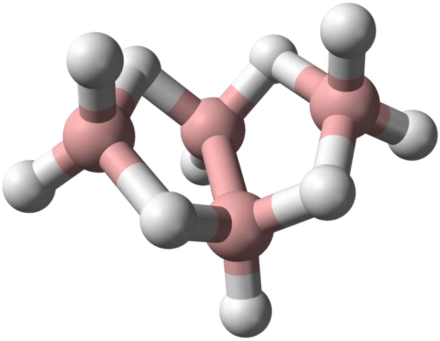
These compounds are called boranes, and they are neither stable nor normal.



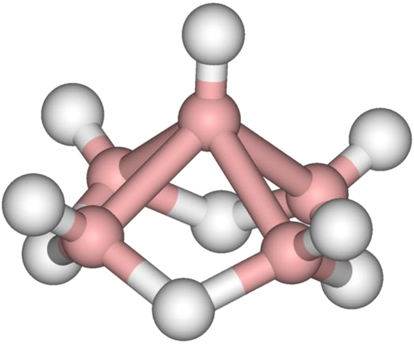
Borane, BH_3



Diborane, B_2H_6



Tetraborane, B_4H_{10}



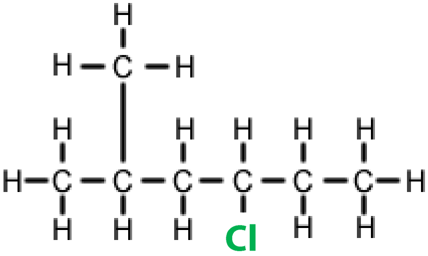
Pentaborane-[9], B_5H_9

LIE #45. Organic molecules need to be named with the lowest numbers possible

Not true. There's a priority order that needs to be obeyed when naming organic molecules, and it isn't taught at VCE level. Benzene rings and carboxyl groups take priority, and side-chains (e.g. methyl groups) take the lowest priority.

Following the organic naming rules taught at VCE sometimes result in the wrong name being used.

For example:



CORRECT NAME: 3-chloro-5-methylhexane

INCORRECT NAME: 4-chloro-2-methylhexane

At VCE level, you learn that the second name is 'correct' even though this name unfortunately *doesn't* follow the IUPAC naming rules. VCAA has accepted both names in examinations.

LIE #46. Molecular substances are all covalent

Wrong again. Potassium bromide, KBr, exists as discrete molecules in the gas phase.

Potassium bromide molecules are the most polar known molecules with a dipole moment of around 10.4 D.

LIE #47. Hydrogen bonding is strong

Hydrogen bonding is about ten times weaker than most covalent bonds. We can prove this with a simple experiment: breaking the hydrogen bonds in water requires 100 °C temperature. Breaking the covalent bonds *within* the water molecules, however, requires about 1000 °C.

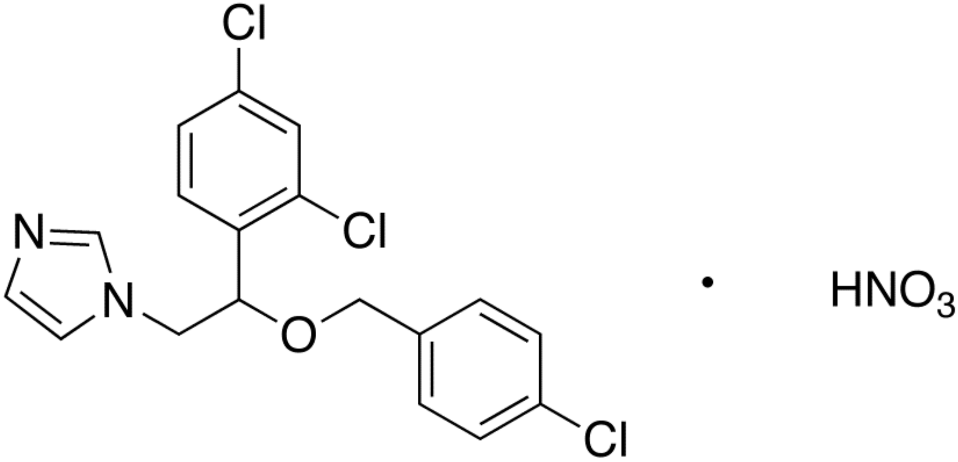
Hydrogen bonding isn't even the strongest type of *intermolecular* bonding. Ion-dipole bonds, which are formed when soluble salts dissolve in water, are stronger than hydrogen bonds.

LIE #48. All nitrates are soluble

Substance that can dissolve in water at concentrations greater than 10 g/100 mL H_2O at 25 °C are considered ‘soluble’.

Barium nitrate sits just above the threshold at 10.5 g/100 mL. However, this is still soluble enough to be considered ‘soluble’.

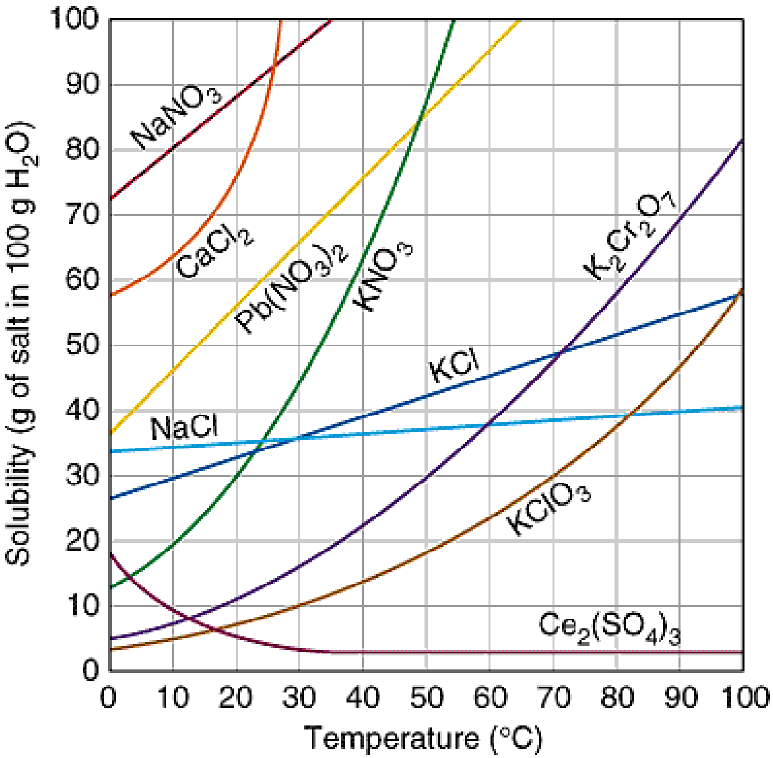
Econazol nitrate has an extremely low solubility of just 0.000148 g/100 mL and is one of the best-known insoluble nitrates. It’s used as a broad-spectrum antibiotic, and its structure is below.



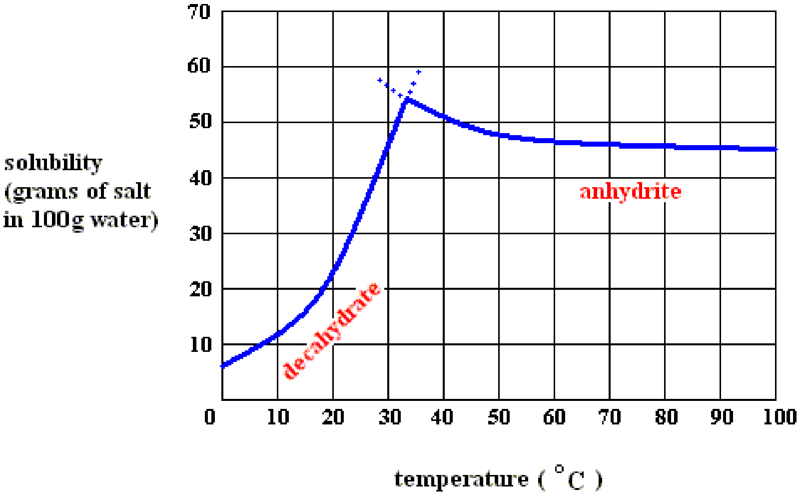
LIE #49. Solubility of solids in liquids increases with increasing temperature

Cerium sulfate has an unusual solubility curve.

While the solubility of most solids in liquid solvents such as water do increase steadily, cerium sulfate's solubility decreases with increasing temperature.



Sodium sulfate is even stranger. It reacts at temperatures of 32 °C or greater, favouring the anhydrous form over the decahydrate. Once the transition has been made, the gradient of the solubility curve changes dramatically, and drops off to an asymptote of around 45 g/100 mL.



Not all solids are more soluble in warm water than in cold water!

LIE #50. Water freezes at 0°C

Pure water actually freezes at -41 °C. This is very different from the 0 °C value given in our textbooks and encyclopaedias because the freezing temperature of water can be increased by the presence of impurities and rough solid surfaces that act as ice nuclei. These ice nuclei are so ubiquitous in our environment (e.g. particulate pollution or sufficiently rough surfaces of water containers) that water freezes at its highest possible temperature, 0 °C, most of the time.

You can do this experiment at home with supercooled water. Take a bottle of pure water (the cheapest mineral water will do because this tends to be relatively pure *reverse osmosis* water) and put it in the freezer. After several hours, gently remove the bottle from the freezer and hit it hard on the table. The agitation will trigger a sudden nucleation of ice crystals inside the bottle. Ice will appear to 'grow' inside upon impact.

Supercooled water freezes upon contact with solid ice

Reference: Moore, Emily and Valeria Molinero. "Structural Transformation In Supercooled Watercontrols The Crystallization Rate Of Ice". *Nature* 479 (2011): 506. Web. 4 Nov. 2016.

~ THE END ~