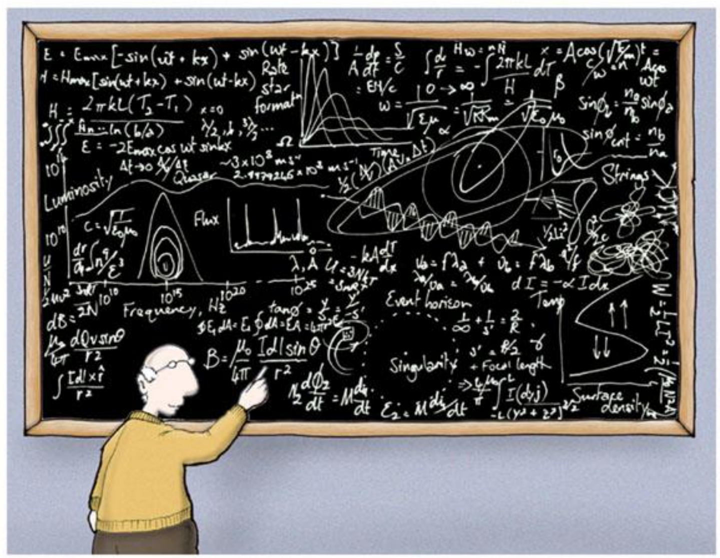
Skills for Stepping up to Scholarship Chemistry

Wellington Chemistry Teachers

December 2021



Astrophysics made simple

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Scholarship Students?

- How do you identify potential Scholarship students?
- When do you identify potential Scholarship students?
- What criteria do you use?
- What skills do scholarship students need?
- How/when do they acquire these skills?

Skills for Stepping up to Scholarship Chemistry

- Understanding the World from a Chemistry Perspective
- Communicating in Chemistry
- Problem Solving using Chemical Principles

From the Scholarship Standard - For Outstanding Performance

Sophisticated integration and abstraction involves **planning,** processing**,** **linking,** and applying chemical principles across all areas of chemistry to solve problems or provide explanations of observations from a chemical perspective.

Stepping up to Scholarship - HINTS From past examiner reports

The best performing candidates most commonly demonstrated the following:

- **read and interpreted questions correctly**
- showed an accurate and detailed understanding of chemical concepts
- were familiar with all the Level 3 and related Level 2 Achievement Standards
- *showed a clear understanding of the language of chemistry, particularly with respect to attractive forces, enthalpy and entropy changes, and molecular shapes.*
- *wrote logical and coherent, concise responses and showed some evidence of planning and linked their knowledge of chemistry directly to the context of the question asked*
- *correctly used chemical vocabulary and defined terms when necessary*
- *provided explanations that were appropriate to the questions rather than being dependent on learned responses (especially for intermolecular forces)*
- *wrote answers that were supported by balanced equations and / or correct formulae*
- **able to use problem solving skills to apply their knowledge of chemistry to unfamiliar situations**
- able to retrieve data that was presented in an unfamiliar form and use it to solve problems or explain given scenarios
- carried out calculations which were logical and clearly laid out - it is essential that candidates are able to solve calculations that involve a variety of steps that are often different from the common methods utilised in NCEA examination questions.
- showed some evidence of practical laboratory work and an understanding of the procedures used

Understanding the World from a Chemistry perspective

How do Chemist's see the world?

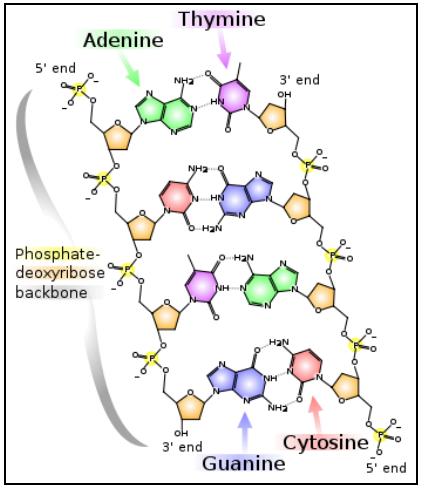
Challenge 1: Integrating observations, particles and symbols

What is chemistry? The big picture

A chemist's view of the world

"There is delight to be had by merely looking at the world, but that delight can be deepened when the minds eye can penetrate the surface of things to see the connections within".

Peter Atkins 'Molecules'



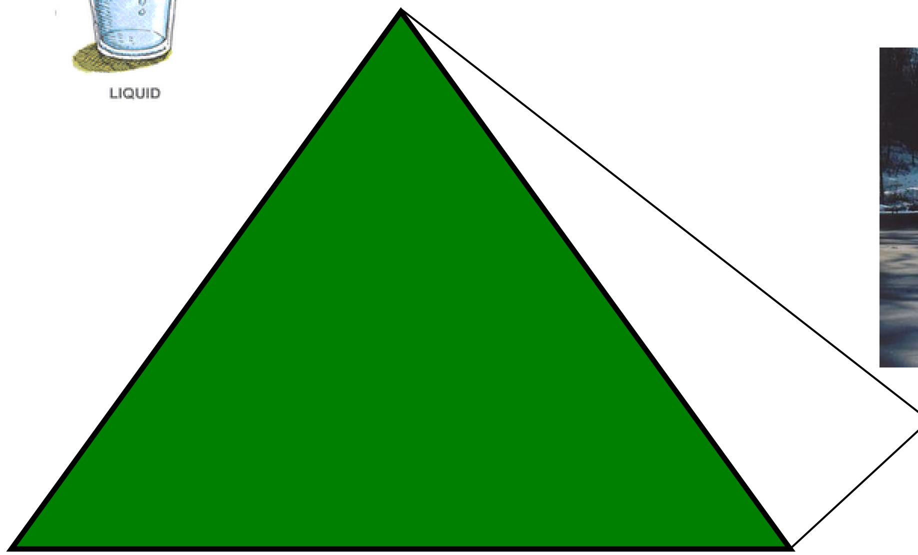
CHEMISTRY IS a way of *understanding the world* from the perspective of the properties and interactions of the *particles* (atoms, ions and molecules) of which all matter is made.

Understanding in chemistry is determined when we address and integrate chemical phenomena in three dimensions:

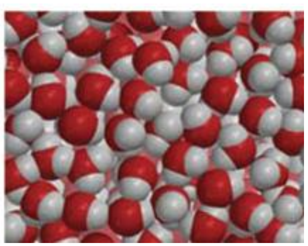
- ***Macroscopic / observations*** : what can be seen touched and smelt (measured)
- ***Sub-microscopic / particles***: atoms, molecules, ions
- ***Symbols***: formulae, equations, calculations and graphs

The Triangle+ of Understanding Chemistry

OBSERVATIONS



CHEMISTRY & SOCIETY



PARTICLES

SYMBOLS

$H_2O(\ell)$

Macroscopic / observations : what can be seen/felt/smelt (measured)

Sub-microscopic / particles: atoms, molecules, ions

Symbols: formulae, equations, calculations and graphs

Most Scholarship questions require integration of all 3 dimensions e.g. using particles to explain observations linked to symbols or writing equations for a given reaction and using this to develop an explanation

Communicating Chemistry - Chemical Literacy

Evidence – Claim - Reasoning

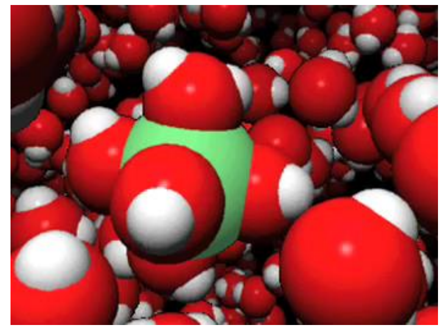
Challenge 2: Logically constructing an explanation for chemistry phenomena

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

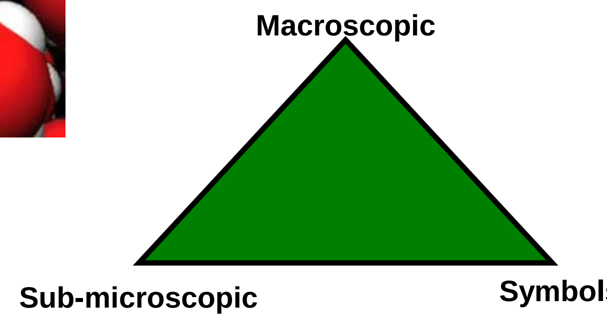
Explaining chemical phenomena

Chemists investigate the ‘molecular’ reasons for the processes that occur in the ‘macroscopic’ world. They often communicate their understanding using symbols.

Example: Reaction of $FeCl_3$ with KSCN



$$[Fe(H_2O)_6]^{3+} + SCN^{-} \rightleftharpoons [Fe(H_2O)_5SCN]^{2+}$$



Linking all 3 dimensions to show understanding in chemistry

- What do we ‘see’?
- How can we explain this using the particles involved and their interactions with each other?
- Can we write an equation to represent this?

‘Translate’ the equation into words that link to the particles and the observations.

A tool for writing logical planned coherent answers

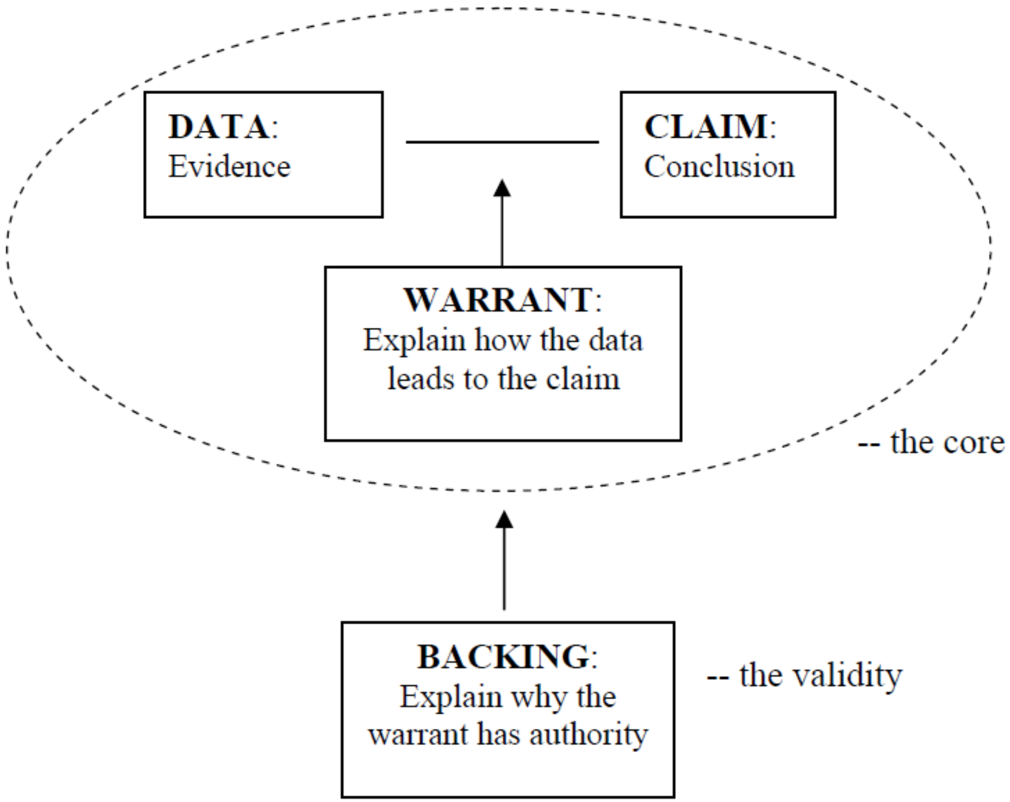


Figure 1. Toulmin's model of argumentation.

Evidence - Claim – (warrant) - Reasoning

Data = Evidence
Measurements / observations on which the claim is based / evidence = provided

Claim
a conclusion derived from the data / **focus of the argument**
= chemical principle (summary)

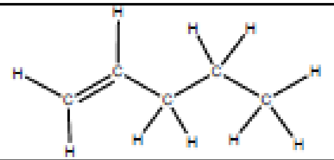
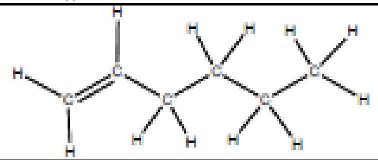
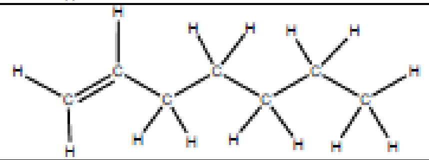
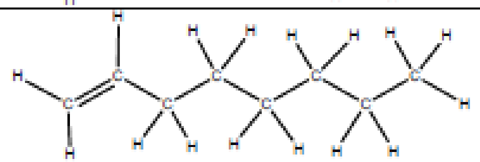
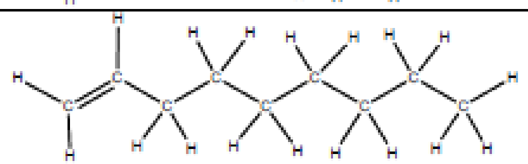
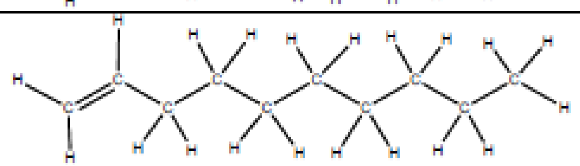
Warrant = link
links data to the claim / supports the claim = summary (one-liner)

Backing - reasoning
additional information or support for the warrant = everything you need to say

Account for the trend seen in the table. Identify the trend (data), state the reason for the trend/focus of your argument (claim), link the claim and the data (warrant) and then provide other supporting information (backing).

Data

Table 1: Boiling Points (Bps) of Some Organic Compounds

Compound	Molecular Structure	Bp (°C)
1-pentene		30
1-hexene		63
1-heptene		94
1-octene		121
1-nonene		147
1-decene		171

Data: Boiling point increasing as length of chain / size of the molecule increases

Claim (focus of argument): **intermolecular forces** get stronger as the length of the chain increases

Warrant: Boiling point increases **because** more energy is needed to separate the molecules as intermolecular forces get stronger

Backing: The molecules are non-polar so the intermolecular forces are instantaneous–induced dipole forces. These forces increase as the size of the electron cloud gets bigger – i.e. with increasing molecular size. So boiling point goes up.

Putting it all together

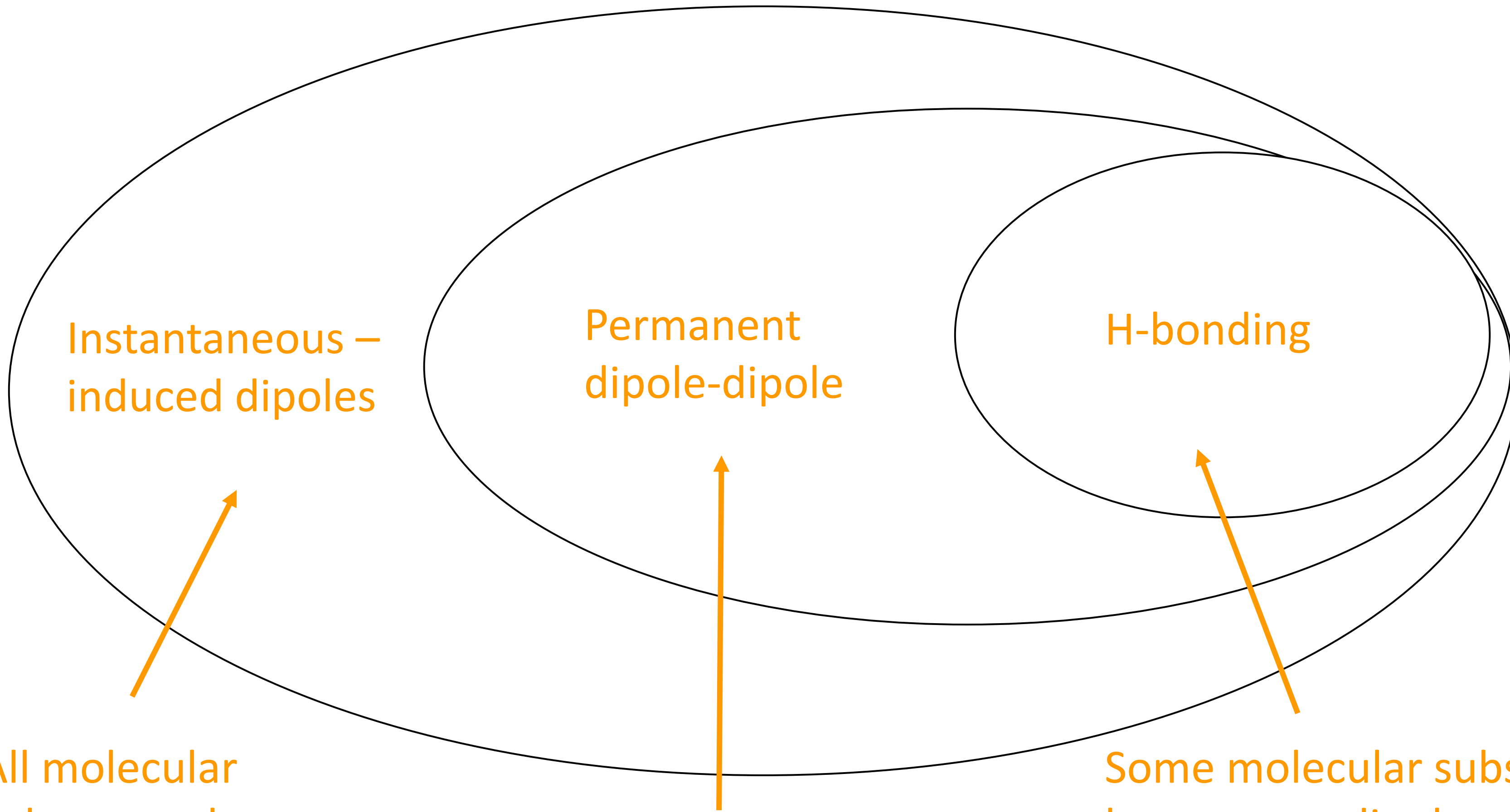
Boiling point increases as the size of the molecule/length of the carbon chain increases because there are stronger intermolecular forces between the larger molecules. As the intermolecular forces get stronger more more energy is needed to separate the molecules from each other in the boiling process.

The molecules are all non-polar so the only intermolecular forces are instantaneous–induced dipole forces (temporary dipole). These increase as the electron cloud gets bigger – i.e. with increasing molecular size. So boiling point goes up.

Some Communication Questions you might get in the exam:

- Comparing melting and boiling points (or solubility) – molecular and ionic compounds
- Shapes of molecules/polarity – emphasis on trigonal bipyramid arrangements
- Stability of compounds/spontaneity of reactions – entropy (often also involves calculation of enthalpy)
- Atomic properties (linked to electron configurations)
- Oxidation and reduction processes (changes in oxidation numbers, electron transfer processes, oxidant/reductant)
- Changes to pH linked to species present in the solution

Intermolecular forces are additive:



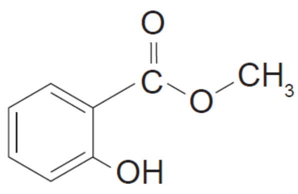
All molecular substances have TEMPORARY DIPOLE-DIPOLE forces (these depend on size of the electron cloud and molecule shape)

Some molecular substances have PERMANENT DIPOLE-DIPOLE as well as Temporary dipole-dipole forces

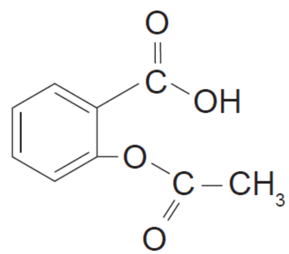
Some molecular substances have strong dipole –dipole forces called HYDROGEN BONDS as well as Temporary Dipole-Dipole forces

Communication Problem 1: (Scholarship Exam 2019)

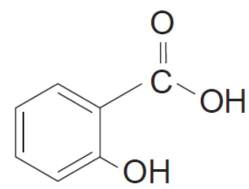
Methyl salicylate (oil of wintergreen) and acetylsalicylic acid (aspirin) are two substances that can be synthesised industrially from salicylic acid. Both are used medicinally, with methyl salicylate used un skin creams such as Deep Heat™ to treat muscle injury and pan, while aspirin is consumed orally in a tablet form to treat pain or reduce blood clotting.
Account for the differences in the melting points.



Oil of wintergreen
(methyl salicylate)
$M(C_8H_8O_3) = 152\ g\ mol^{-1}$
M.P: –8 °C



Aspirin
(acetylsalicylic acid)
$M(C_9H_8O_4) = 180\ g\ mol^{-1}$
M.P: 135 °C



Salicylic acid
$M(C_7H_6O_3) = 138\ g\ mol^{-1}$
M.P: 159 °C

Data shows variation in m.p with *M* and molecule structure

Melting point depends on the sum of all the intermolecular forces between molecules (between temporary and permanent dipoles and H-bonds). Intermolecular forces depend on molecular structure, shape and size. As the total intermolecular force increases, the melting point increases as more energy is needed to separate the molecules.

Temporary dipoles – compare electron density (linked to *M*) + check out 'packing'

Permanent dipoles – all polar so compare shape/position of significant polar bonds

Hydrogen bonds – all are able to form H-Bonds between molecules so compare the number of H-bonds possible between molecules

Link to **melting Points** by considering the overall sum of the intermolecular forces

Answer - 1 possible way of organising the discussion

Comparing **temporary dipole forces**: acetylsalicylic acid > methyl salicylate > salicylic acid. These forces form because of the random movement of electrons. An increase in molar mass means a greater number of electrons, increasing the size of the temporary dipole, so intermolecular forces increase. These forces also become stronger as molecules get closer together which will have the greatest impact within salicylic acid, where the molecules are able to **pack closest.**

Comparing **permanent dipoles:** these result from the presence of C–O, C=O, and O–H bonds. However, the the overall net dipoles of the molecules of methyl salicylate and acetylsalicylic acid are less than for salicylic acid due to the ester groups which have non-polar $–CH_3$ groups.

Comparing **Hydrogen bonding:** H-bonds form between the lone pairs of electrons on O atoms and the nearby slightly positively charged H atoms. These H atoms are positively charged as the O atoms to which they are covalently bonded have a high electronegativity, resulting in the withdrawal of electron density from the atoms. Salicylic acid has greatest capacity to form hydrogen bonds, with two positions able to form such attractions – the –OH hydroxyl group, and –COOH carboxyl group. The carboxyl –COOH group is able to form a greater number of hydrogen bonds due to the presence of both carbonyl C=O and hydroxyl –OH groups. In methyl salicylate the –COOH group is replaced with an ester group, limiting the ability for the molecule to form hydrogen bonds, Similarly, in acetylsalicylic acid, the –OH group is replaced with an ester group, again limiting the formation of hydrogen bonds.

Linking to **Melting Points**. Overall the sum of the intermolecular forces in salicylic acid is the greatest in spite of it having the least number of electrons. This will be due to the increased packing (a result of the molecule shape) the higher polarity and greater capacity for H-bonding. Hence it has the highest melting point. Acetylsalicylic acid and methyl salicylate have lower melting points because there is less capacity for H-bonding and the molecules are less polar with methyl salicylate being the lowest as it has smaller temporary dipole attractions. The significantly lowered melting point of methyl salicylate may also be due to internal hydrogen bonding occurring within the molecules, reducing the capacity for the molecules to form attractions with other nearby molecules. (Dimerisation may also occur between molecules with the –COOH groups, and the dimer units will have greater temporary dipole forces and therefore higher melting points).

Note that answer includes brief description of how forces form/operate

Communication Problem 2: (Scholarship Exam 2020)

Account for the following observations using thermodynamic principles:

1. Oxygen gas dissolves in water at room temperature.
2. The reaction between hydrogen gas, $H_2(g)$, and chlorine gas, $Cl_2(g)$, to form hydrogen chloride gas, $HCl(g)$, is spontaneous at room temperature.

Data: Spontaneous reaction $O_2(g) \rightarrow O_2(aq)$

Claim: Entropy change, ΔS, will be positive for this reaction

Warrant: For spontaneity, entropy (of universe) must increase

$$\Delta S(universe) = \Delta S(surroundings) + \Delta S(system) > 0$$

Backing: $\Delta S(system) < 0$ because ......

$\Delta_r H < 0$ because new 'bonds' formed So $\Delta S(surroundings > 0$

Since $\Delta S(universe) > 0 \Rightarrow \Delta S(surroundings)$ is sufficient to compensate for $\Delta S(system)$

Data: Spontaneous reaction $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

Backing: $\Delta S(system) = 0$ because .....

Hence $\Delta S(surroundings) > 0$ because $\Delta S(universe) > 0$

$\Delta S(surroundings) > 0$ because $\Delta_r H < 0$ because:

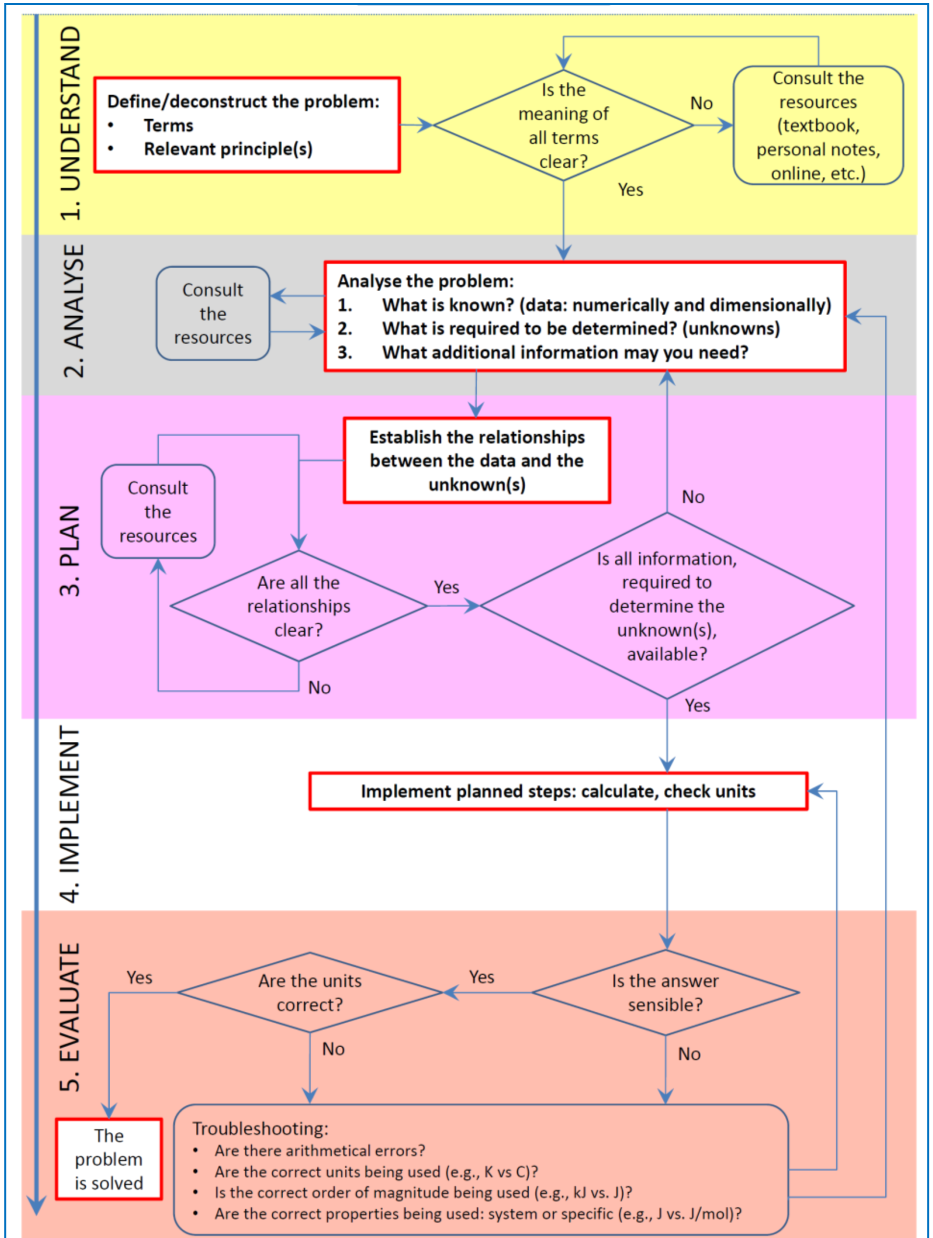
new bonds formed (H-Cl) release more energy when formed than needed to break H-H and Cl-Cl

Problem Solving

What you do when you don’t know what to do

Challenge 3: Have a plan

What to do when you don’t know what to do – a tool



1. **Understand – define/deconstruct the problem:** What is the question? What chemical principles are involved in this problem? Can you identify key types of chemical reactions? (oxidation – reduction, acid – base, precipitation). What do the terms mean?
2. **Analyse:** What is known? What is unknown? Identify key pieces of information or surplus information not needed - maybe draw a flow chart. What else is needed to solve the problem (equations, formulae etc)?
3. **Plan:** What are the connections between the known and the unknown? What steps do I need to take to make the connections?
4. **Implement:** Calculations etc
5. **Evaluate:** Does the answer make sense? (units, order of magnitude etc). Did I answer the question(s)?

Yuriev, E., Naidu, S., Schembri, L. S. and Short, J. L. (2017) Scaffolding the development of problem-solving skills in chemistry: guiding novice students out of dead ends and false starts. Chemistry Education Research and Practice, 18, 486-504.

Problem Solving 1 (SCHOLARSHIP 2010) (+ **Communication**)

Most metal sulfides are soluble in water.

Discuss how changing the pH affect the solubility of thallium(I) sulfide?

K_s (Tl_2S) = 6×10^{-22} pK_a(HS^-) = 11.96.

Understand Solubility & acid-base equilibrium. Effect of increasing/decreasing pH/[H_3O^+]

Analyse $Tl_2S(s) \rightleftharpoons 2Tl^+(aq) + S^{2-}(aq)$ $K_s = 6 \times 10^{-22}$

$HS^- + H_2O \rightleftharpoons S^{2-}(aq) + H_3O^+(aq)$ pK_a(HS^-) = 11.96

Write equations for the '*K*' data given

So: S^{2-} is a weak base (conjugate base of a weak acid)

$S^{2-} + H_2O \rightleftharpoons HS^-(aq) + OH^-(aq)$

**Write equations for the *K* values

Plan Use equilibrium equations and common ion effect/Le Chatelier's pple to discuss changes with pH increase and decrease

Implement

Decreasing pH: [OH^-] is decreased $H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O$

[S^{2-}] is decreased: $S^{2-}(aq) + H_2O(\ell) \rightarrow HS^-(aq) + OH^-(aq)$

This causes more Tl_2S (*s*) to dissolve to restore [S^{2-}]. $Tl_2S(s) \rightleftharpoons 2Tl^{2+}(aq) + S^{2-}(aq)$

Therefore the solubility of Tl_2S increases as the pH decreases.

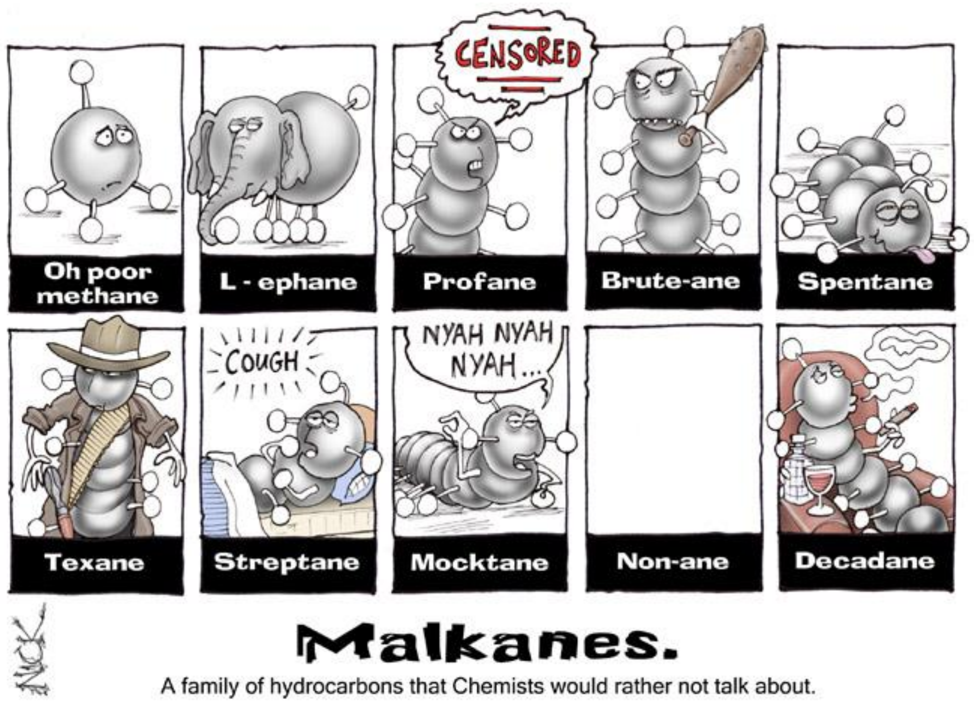
Increasing pH: Increasing [OH^-] increases [S^{2-}]

This causes more Tl_2S (*s*) to precipitate to use up [S^{2-}].

So the solubility of Tl_2S decreases as the pH of the solution increases.

Problem Solving: Organic Chemistry

- READ the WHOLE question FIRST
- Construct a ***flow chart*** using letters and formulae
- Include any important ***extra*** information ***next*** to your flowchart
- Consider information from spectra and ***add*** to the information
- Identify key reactions using the reagents
- Identify the functional groups AND isomerism
- Choose a starting point (usually the unknown that you have the most information about) and draw possible isomers
- Identify the isomer/isomers that best fits the data then……….



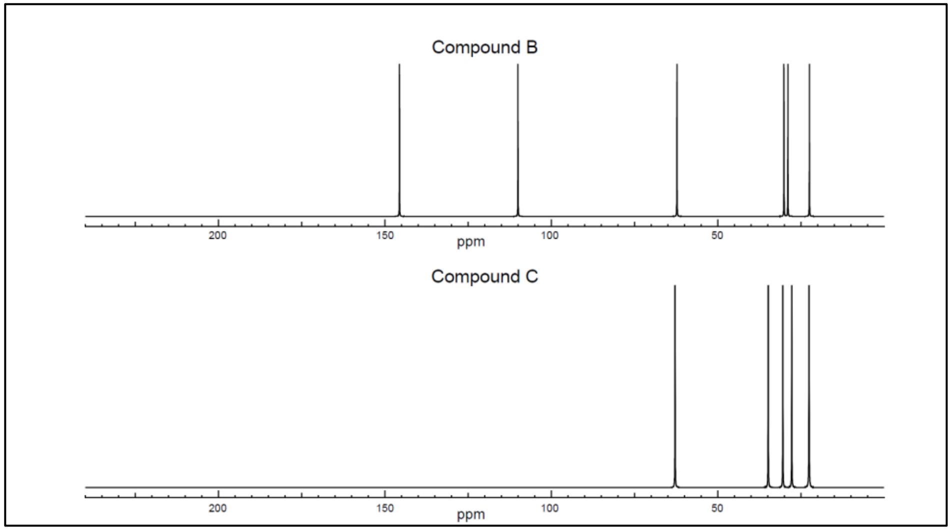
Problem Solving 2 (SCHOLARSHIP 2019)

Compound **A**, with an unknown structure, was isolated from a reaction pathway and determined through high-resolution mass spectrometry to have a molecular formula of $C_6H_{13}OCl$. In order to deduce the structure of Compound **A**, the following reactions were carried out.

Compound **A** was reacted with NaOH(*alc*) to produce a single Compound **B**, which was separated into two samples. The 1st sample was reacted with H_2 / Pt to give Compound **C**, with the molecular formula $C_6H_{14}O$, which showed no optical activity. (The 13C NMR spectra for Compounds **B & C** are provided booklet). The 2nd sample of Compound **B** was reacted with dilute H_2SO_4, producing two products, Compounds **D** and **E**. After separation, each compound was analysed and both produced molecular ion peaks (M+) at 118 m/z. Compounds **D** and **E** were each separately reacted with acidified potassium permanganate solution, H^+ / MnO_4^-, to give Compounds **F** and **G** respectively. Analysis of Compounds **F** and **G** with mass spectrometry determined Compound **F** to have a greater molar mass than Compound **G**. Compound **G** was miscible with water, but after treatment with $SOCl_2$, followed by reaction with an equimolar amount of methanol, formed Compound **H**, which was found to be immiscible with water.

Identify and give the structures of Compounds **A** to **H**.

^{13}C NMR



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Compound **G** was miscible with water, but after treatment with $SOCl_2$, followed by reaction with an equimolar amount of methanol, formed Compound **H**, which was found to be immiscible with water.

Analyse: What is is known? *Map data and identify reaction types and functional groups*

A ($C_6H_{13}OCl$) $\xrightarrow{\text{NaOH}(alc)}$ **B** — Elimination of –Cl so B has a double bond and A has haloalkane; Single product so –Cl is at the end of the chain

B $\xrightarrow{H_2/Pt}$ **C** ($C_6H_{14}O$) — C is not chiral — Addition to double bond

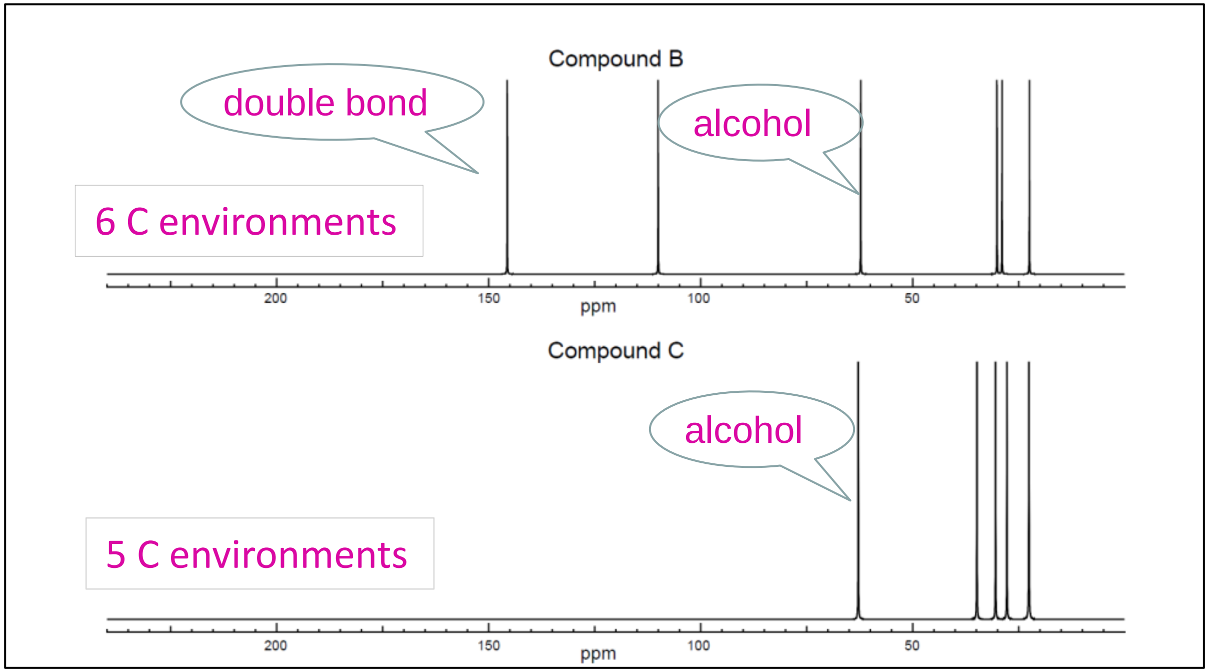
B $\xrightarrow{\text{dil. } H_2SO_4}$ **D** + **E** — Addition of H_2O - 2 products so B is not symmetrical; D and E are alcohols

D $\xrightarrow{MnO_4^-/H^+}$ **F**

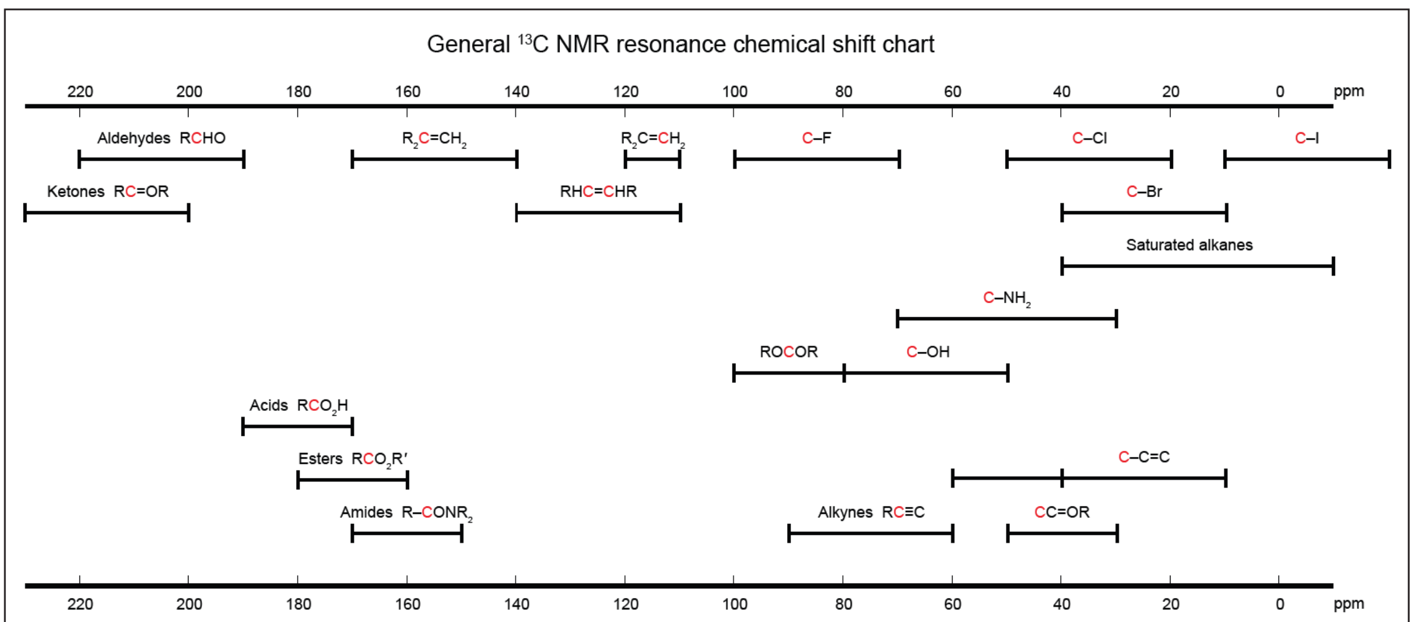
E $\xrightarrow{MnO_4^-/H^+}$ **G**

Oxidation of alcohol
- Possible products = acid, ketone

G $\xrightarrow[CH_3OH]{SOCl_2}$ **H** — Substitution of –OH for –Cl (acid to acid chloride); The esterification so **G** has acid and **H** ester



^{13}C NMR RESONANCE SHIFTS



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B $\xrightarrow{H_2/Pt}$ **C** ($C_6H_{14}O$) — **C** is not chiral. Addition to double bond. **C** is a saturated alcohol. **C -** 5 C environments, -OH peak (75 ppm)

B $\xrightarrow{\text{dil. } H_2SO_4}$ **D** + **E** — Addition of H_2O - 2 products so B is not symmetrical. D and E are alcohols. **D & E –** M+ = 118 m/z $\Rightarrow$ $C_6H_{14}O_2$ so 2 -OH

D $\xrightarrow{MnO_4^-/H^+}$ **F**

E $\xrightarrow{MnO_4^-/H^+}$ **G**

Oxidation of alcohol - Possible products = acid, ketone. M(**F**) > M(**G**). **F** = acid present, **G** = ketone present

G $\xrightarrow[CH_3OH]{SOCl_2}$ **H** — Substitution of –OH for –Cl (acid to acid chloride). The esterification so **G** has acid and **H** ester. **D** = 1º alcohol, **E** = 2º alcohol

Plan: *Draw possible isomers of C 2º alcohol and identify which one(s) meets the criteria*

A ($C_6H_{13}OCl$) $\xrightarrow{NaOH(alc)}$ B

Elimination of –Cl so B has a double bond and A has haloalkane

Single product so –Cl is at the end of the chain

A also has -OH

B - 6 C environments

-OH peak (75 ppm)

B $\xrightarrow{H_2/Pt}$ C ($C_6H_{14}O$)

Addition to double bond

C is not chiral

C - 5 C environments

-OH peak (75 ppm)

C is a saturated alcohol

B $\xrightarrow{H_2O/H^+}$ D + E

Addition - 2 products so B is not symmetrical

D and E are alcohols

D & E – M+ = 118 m/z ⇒ $C_6H_{14}O_2$ so 2 -OH

D $\xrightarrow{MnO_4^-/H^+}$ F

E $\xrightarrow{MnO_4^-/H^+}$ G

Oxidation of alcohol

Possible products = acid, ketone

M(**F**) > *M*(**G**)

F is more oxidised than **G**

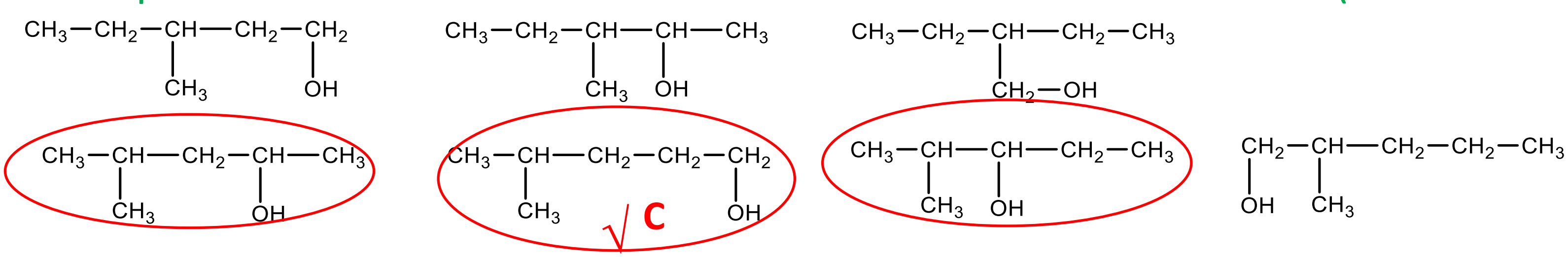
G $\xrightarrow[CH_3OH]{SOCl_2}$ H

Substitution of –OH for –Cl

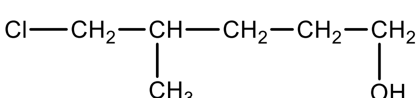
D and **E** both have 1° alcohol

Reaction with CH_3OH suggests esterification so **G** has acid and **H** is ester

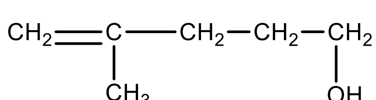
Plan: Draw possible isomers of **C** and decide which ones meet the criteria (5 C environments)



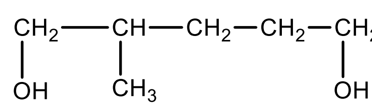
A must have –Cl at the other end of the chain



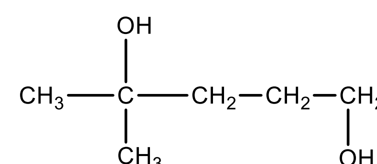
A



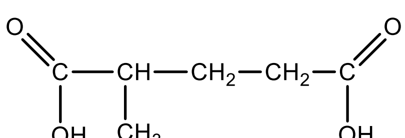
B



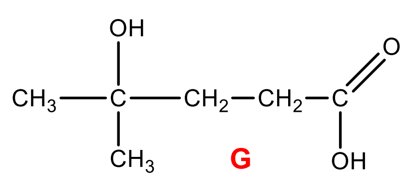
D



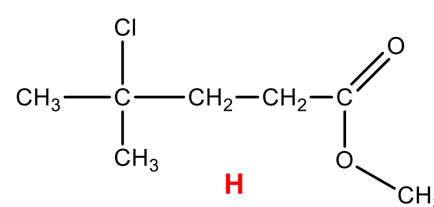
E



F

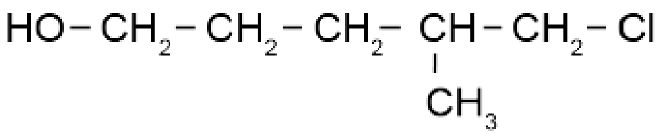


G

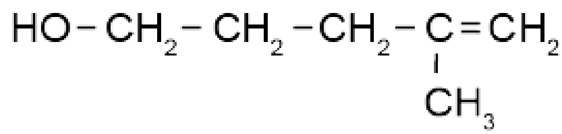


H

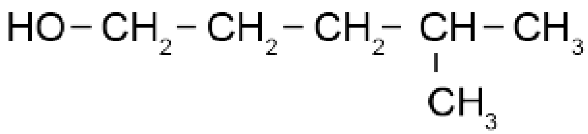
A: 5-chloro-4-methylpentan-1-ol



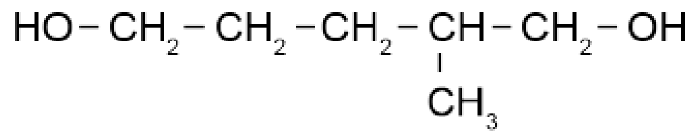
B: 4-methylpent-4-en-1-ol



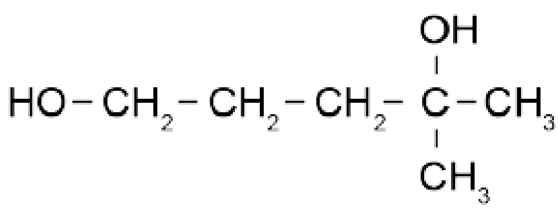
C: 4-methylpentan-1-ol



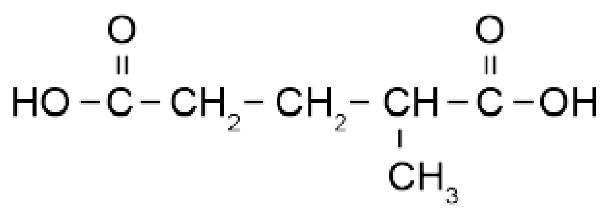
D: 4-methylpentan-1,5-diol



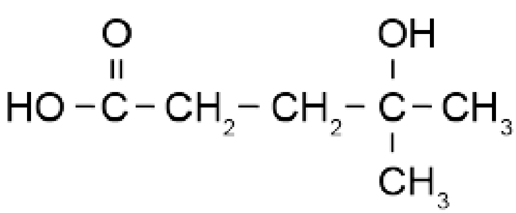
E: 4-methylpentan-1,4-diol



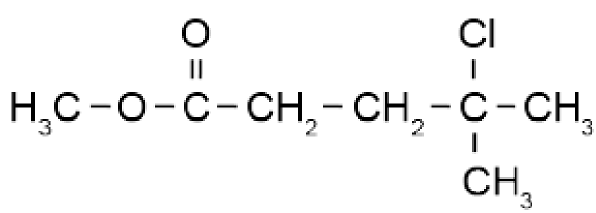
F: 4-methylpentan-1,5-dioic acid



G: 4-hydroxy-4-methylpentanoic acid



H: methyl 4-chloro-4-methylpentanoate



Note: Names were not required

Problem Solving – Calculations

- Thermochemistry + Stoichiometry

Step Up = Δ_rH to be calculated from Δ_rH^o + limiting reagents (See Q4b EXAM 2020)

- Titrations

Step Up = redox or precipitation reaction and/or back titration, concentration expressions ($g\ mL^{-1}$ etc)

- Empirical/molecular formulae (Level 2)
- Aqueous – pH/solubility

Step Up - Maybe a different starting point for finding concentration(Q1a EXAM 2020)

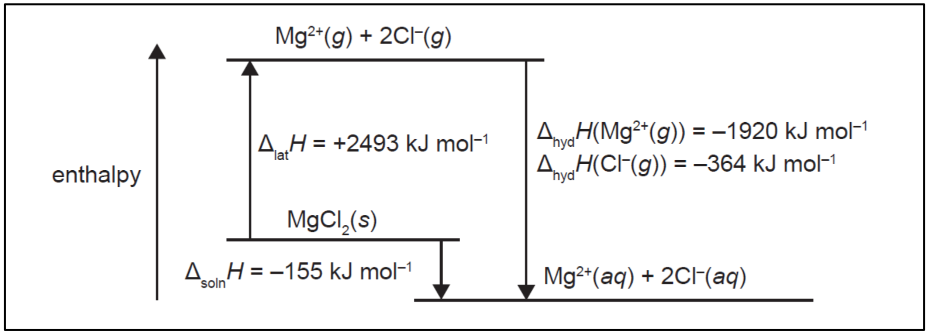
- Solubility/precipitation

Special notes – Calculations
All working should be shown in calculations. Numerical answers should be rounded to an appropriate number of significant figures. Correct units must be included. Explanations and calculations are expected to be well set out and concise.

Calculations (should be) completed with logical, well laid out, detailed working, with use of correct significant figures and units (only rounding up final answer). Candidates (should be) able to solve calculations involving a variety of steps that maybe different from common methods utilised in NCEA examination questions

Thermochemistry (2019)

The enthalpy of solution, $\Delta_{soln}H$, is for 1 mol of an ionic solid dissolving in water. $\Delta_{soln}H$ can be calculated from lattice enthalpy, and hydration enthalpy for the ions involved, as shown in the diagram for $MgCl_2$.



Single-use instant cold and hot packs often involve the dissolution of an ionic solid. Both types consist of a small plastic bag that contains a measured volume of water plus an anhydrous salt in the main compartment. Upon twisting, squeezing or striking the pack, the inner bag is ruptured, releasing the water and dissolving the salt. As the salt is dissolved, the temperature of the water can increase or decrease, depending on the composition of the pack. The processes occurring in each type of pack are thermodynamically favoured.

One such pack contains 115 mL of water and 39.0 g of ammonium nitrate, $NH_4NO_3(s)$.

Calculate the temperature that the pack will theoretically reach when it is activated.

Assume the pack is at room temperature, 25 °C.

$M(NH_4NO_3) = 80.0$ g mol^{-1} $c(H_2O) = 4.18$ J °C^{-1} g^{-1}

Standard Enthalpy of Hydration / kJ mol^{-1}	
$NH_4^+(g)$	–307
$NO_3^-(g)$	-314
Standard Lattice Enthalpy / kJ mol^{-1}	
NH_4NO_3 (s)	646

Understand (Question? Chemical principles?)

Calculate final temperature of the heat pack

Uses Thermochemical principles

Analyse (known, unknown, links, what's missing?)

Known: $T_{initial} = 25\ ^oC$ $V(H_2O) = 115$ mL $m(NH_4HO_3) = 39.0$ g Unknown: T_{final}

Links: $q = mc\Delta T$ $\Delta_{soln}H^o = \frac{-q}{n}$ $n = \frac{m}{M}$ Missing: $\Delta_{soln}H$

Plan: Use data to find $\Delta_{soln}H$ then use equations and data to calculate ΔT

Understand (Question? Chemical principles?)

Calculate final temperature of the heat pack. Uses Thermochemical principles

Analyse (known, unknown, links, what's missing?)

Known: $T_{initial} = 25\ ^oC$ $V(H_2O)$ = 115 mL $m(NH_4HO_3)$ = 39.0 g Unknown: T_{final}

Links: $q = mc\Delta T$ $\Delta_{soln}H^o = \frac{-q}{n}$ $n = \frac{m}{M}$ Missing: $\Delta_{soln}H$

Plan:

Use data to find $\Delta_{soln}H$ then use equations and data to calculate ΔT

Implement:

$\Delta_{soln}H^o = \Sigma\Delta H^o(\text{lattice}) + \Sigma\Delta H^o(\text{hydration})$

$NH_4NO_3(s) \rightarrow NH_4^+(aq) + NO_3^-(aq)$

$\Delta_{soln}H(NH_4NO_3) = –307\text{ kJ mol}^{-1} + –314\text{ kJ mol}^{-1} + 646\text{ kJ mol}^{-1} = +25\text{ kJ mol}^{-1}$

$m(NH_4NO_3)$ = 39.0 g

$n(NH_4NO_3) = \frac{39.0\text{ g}}{80.0\text{ g mol}^{-1}}$ = 0.4875 mol

$q_{system} = \Delta_{soln}H \times n = 25\text{ kJ mol}^{-1} \times 0.4875\text{ mol} = 12.19\text{ kJ (12190 J)}$

$\Delta T_{solution} = \frac{-q_{system}}{c(H_2O)\times m(solution)} = \frac{-12190\text{ J}}{4.18\text{ J }^oC^{-1} \times 154\text{ g}} = -18.94\ °C$

Final Temp = 25 °C – 18.94 °C = **6.07 °C**

Titration (SCHOLARSHIP 2014)

A bottle of household bleach contains the following information:
Active ingredients: Sodium hypochlorite 42 g L^{-1} (available chlorine 4.0% m / V), available chlorine by 'use by date' 2.0% m / V, sodium hydroxide 9 g L^{-1}.

The following procedure is carried out to determine the extent of the decomposition of the contents of a bottle of household bleach. "A 20.00 mL sample of bleach is diluted to 250.0 mL using a volumetric flask. Excess potassium iodide is added to a 10.00 mL sample of diluted bleach solution, along with 10 mL of dilute sulfuric acid. $H^+ + 2I^- + OCl^- \rightarrow I_2 + Cl^- + OH^-$
The liberated iodine is titrated with a standard sodium thiosulfate ($Na_2S_2O_3$) solution of concentration 0.04562 mol L^{-1}. The end point is determined by the change of colour of a starch indicator and, on average, required 16.69 mL. $2S_2O_3^{2-} + I_2 \rightarrow 2I^- + S_4O_6^{2-}$
Determine the extent of the decomposition of the bleach by comparing the available chlorine (% m/V) in the bottle, with that on the label.

$M(NaOCl) = 74.5$ g mol^{-1}

Understand (Question? Chemical principles?)

Determine the extent of the decomposition of the bleach (OCl^-)
- Need to find available chlorine from titration data (% m/V) & compare with that on the label.

Analyse (known, unknown, links, what's missing?)

Given (known): $c(S_2O_3^{2-}) = 0.04562$ mol L^{-1} and $V(S_2O_3^{2-}) = 16.69$ mL Dilution factor: 20:250

In titration V(bleach) = 10.00 mL 42 g L^{-1} = available chlorine 4.0% m/V

Links to unknown (OCl^-): $2S_2O_3^{2-} + I_2 \rightarrow 2I^- + S_4O_6^{2-}$, $H^+ + 2I^- + OCl^- \rightarrow I_2 + Cl^- + OH^-$

$M(NaOCl) = 74.5$ g mol^{-1}

Understand (Question? Chemical principles?)

Determine the extent of the decomposition of the bleach (OCl^-)

- Need to find available chlorine from titration data (% m/V) & compare with that on the label.

Analyse (known, unknown, links, what's missing?)

Given (known): $c(S_2O_3^{2-})$ = 0.04562 mol L^{-1} and $V(S_2O_3^{2-})$ = 16.69 mL Dilution factor: 20:250

In titration V(bleach) = 10.00 mL 42 g L^{-1} = available chlorine 4.0% m/V

Links to unknown (OCl^-): $2S_2O_3^{2-} + I_2 \rightarrow 2I^- + S_4O_6^{2-}$, $H^+ + 2I^- + OCl^- \rightarrow I_2 + Cl^- + OH^-$

Plan: $n(S_2O_3^{2-}) \rightarrow [OCl^-]_{diluted} \rightarrow [OCl^-]_{original} \rightarrow$ g L^{-1} $\rightarrow$ % decomposition

Implement: $n(S_2O_3^{2-}) = 0.04562 \times 0.016687 = 7.612 \times 10^{-4}$ mol $= 2n(I_2)$

$n(I_2) = n(OCl^-) = \frac{1}{2}n(S_2O_3^{2-}) = \frac{1}{2} \times 7.612 \times 10^{-4}$ mol $= 3.8062 \times 10^{-4}$ mol

$c(OCl^-) = \dfrac{0.00038062 \text{ mol}}{0.01000 \text{ L}} = 0.038062$ mol L^{-1} (10.00 mL of bleach used)

$c(OCl^-)_{undiluted} = \dfrac{250}{20} \times 0.038062$ mol L^{-1} = 04758 mol L^{-1}

$c(NaOCl)$ = 0.4758 mol L^{-1} × 74.5 g mol^{-1} = 35.45 g L^{-1}

% available chlorine: 42 g L^{-1} ≡ 4.0% In sample: $\dfrac{35.45}{42} \times 4.0\% = 3.38\%$

Extent of decomposition (compare result to original):

% decomposed = $\dfrac{4.00 - 3.38}{4.00} \times 100 =$ 15.6% decomposed

Evaluate – Did you answer the question?

What's the plan??

Level 2 Contexts

1. **Communication Skills**
    - **Boiling/meting point trends** (ionic/metallic/network/molecular)
    - **pH/Conductivity** (weak/strong acids and bases)
    - **Explaining observations** (redox reactions, precipitation reactions)
2. **Problem Solving**
    - **Organic pathways**
    - **Volumetric Analysis** (redox titrations, back titrations, precipitation titrations)
    - **Balancing Redox equations**

What students can do to prepare

- Know your Level 2 and 3 chemistry thoroughly - try out 'scholarship' questions once you are working at 'excellence' for Level 3.
- **Practise answering 'extended writing' questions and check for misconceptions. Practise planning your answers.**
- **Practise solving problems – find a process that works for you and try to come up with a solution without checking the answers till you have something to check!**
- Get used to showing your working in calculations AND the appropriate number of significant figures
- (Get someone to check your answers and give you feedback not just about the accuracy of your answer but about the logic of your discussion and the layout of your calculations)