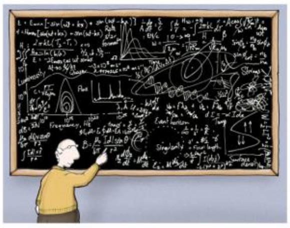
STEPPING UP TO SCHOLARSHIP CHEMISTRY

HUTT WORKSHOP

12 May 2019



Astrophysics made simple

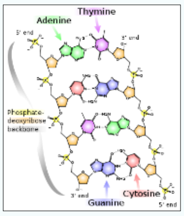
Dr Suzanne Boniface
School of Chemical and Physical Sciences
Suzanne.Boniface@vuw.ac.nz

CHEMISTRY – WHAT'S IT ALL ABOUT?

WHAT IS CHEMISTRY?

"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'

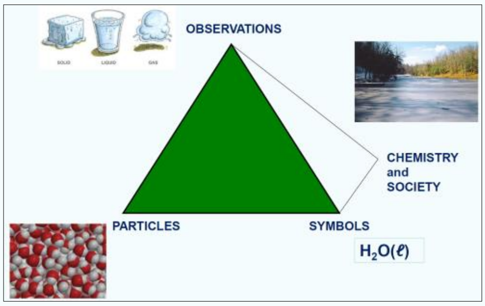


CHEMISTRY IS a way of understanding the world from the perspective of the properties and interactions of the atoms ions and molecules of which all matter is made.

CHEMISTS work in a range of different areas to isolate and synthesise new compounds, predict the properties and reactions of compounds sometimes using mathematical modelling, carry out measurements on chemical systems for analysis or treatment

HOW CHEMISTS VIEW THE WORLD

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

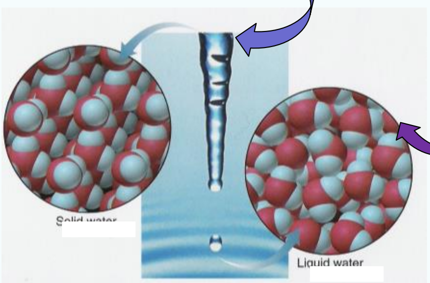


Three dimensions to understanding chemistry:

- ***macroscopic world*** – observing chemical reactions
- ***sub–microscopic world*** of atoms, molecules and ions
- ***symbolic world*** formula and equations

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



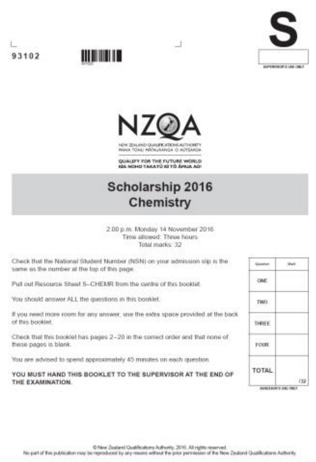
SYMBOLS:
formulae, equations

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

NINE BIG IDEAS OF CHEMISTRY

- Matter is atomic
- Elements display periodicity
- Chemical bonds form when electrons pair
- Molecular shape
- There are residual forces between molecules
- Energy is conserved
- Entropy tends to increase
- There are barriers to reaction
- There are only four types of reactions -
  - the transfer of a proton (acid-base reactions);
  - the transfer of an electron (redox reactions);
  - the sharing of electrons (radical reactions);
  - the sharing of electron pairs (Lewis acid-base reactions).

THE SCHOLARSHIP EXAM


93102

S

SUPERVISOR'S USE ONLY

NZQA

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

QUALIFY FOR THE FUTURE WORLD
KIA NOHO TAKATŪ KI TŌ ĀMUA AO!

Scholarship 2016
Chemistry

2.00 p.m. Monday 14 November 2016
Time allowed: Three hours
Total marks: 32

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

Pull out Resource Sheet S–CHEMR from the centre of this booklet.

You should answer ALL the questions in this booklet.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–20 in the correct order and that none of these pages is blank.

You are advised to spend approximately 45 minutes on each question.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Question	Mark
ONE	
TWO	
THREE	
FOUR	
TOTAL	/32

ASSESSOR'S USE ONLY

Mark criteria

7 - 8 outstanding performance

5 - 6 scholarship performance

3 - 4 demonstrates understanding

1 - 2 meagre understanding relevant to the topic

Scholarship is marked using a scale of 0 to 8 for each question. A mark of 8 or 7 is given for an Outstanding answer. This is likely to show strong evidence of integration and synthesis, be as good as could be expected under examination conditions, and be accurate, comprehensive, coherent, lucid, and perceptive. A mark of 6 or 5 indicates a clear Scholarship-level answer, while a 4 represents a marginal response.

ASSESSMENT SPECIFICATIONS

Format of the assessment

There will be no more than four questions. Questions may be open-ended or structured in a step-wise fashion.

Special notes

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.

Content/context details

- Questions may be asked within a variety of appropriate contexts, some of which may be unfamiliar to the candidates. Some questions may involve extended discussion, where the candidate needs to judge what is required.
- The assessment will be derived from a selection of the content in the Level 2 and 3 chemistry achievement standards.
- Questions may require skills developed during practical work, such as processing and evaluation of data or information.

rom old assessment specs:
ontent will be limited to the knowledge of:
hermochemical principles and properties of particles and substances, properties of rganic compounds, equilibrium principles in aqueous systems, oxidation-reduction rocesses.

WHAT THE REPORTS SAY

2014

It is disappointing to see so many candidates approaching this examination with only a limited understanding of the chemical principles assumed to be part of Level 3 NCEA. Discussions about the reasons for observations, particularly related to periodic trends and intermolecular forces, provide insight into the depth and accuracy of a candidates understanding of atoms, molecules, structure and bonding. Hence it was disappointing that a large number of candidates could not correctly compare the ionisation energies of Na and Mg and showed a limited understanding of ionic and metallic bonding.

Candidates appeared more confident in their discussions of intermolecular forces but it is disappointing at this level to see learned responses being given as reasons without checking the appropriateness of the response for the data given. Many candidates were unable to extend their knowledge to more complex situations than that usually provided in Level 3, thus being unable to meet the scholarship standard. It is the ability to think critically and solve problems that require unfamiliar procedures / methods that helps to identify candidates who are working at scholarship level.

There was little evidence of 'planned' answers where discussions were required. Often students seemed to write all they knew, for example about intermolecular forces and did not relate this knowledge to the specifics of the graph/data given in the question.

WHAT THE REPORTS SAY

The lack of equations in chemistry discussions is also a concern. When reactants and products or 'left hand side and right hand side' of an equilibrium reaction are discussed it is expected that an equation would also be present. Similarly, when calculating *E*º for a 'cell' there must be a link to the cell and this is usually through a chemical equation. Candidates should be encouraged to add annotated diagrams to their discussions as this can lead to more concise explanations, for example, when describing hydrogen bonds.

The best performing candidates most commonly demonstrated the following:

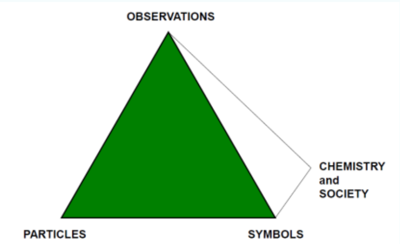
- read and interpreted questions correctly
- wrote logical and coherent responses, showed evidence of planning linking chemistry concepts to the context of the question asked
- correctly used chemical vocabulary and defined terms when necessary
- wrote answers that were supported by balanced equations and correct formulae
- presented accurate calculations, showed working clearly and used significant figures appropriately
- showed understanding of laboratory procedures
- showed an accurate comprehensive understanding of chemical concepts
- applied their knowledge in unfamiliar settings
- were familiar with all the prescribed Level 2 and 3 Standards
- Were able to retrieve data that was presented in an unfamiliar form and use it to solve problems or explain given scenarios

CHEMICAL LITERACY

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



LANGUAGE

Take care to differentiate between the macroscopic and sub-microscopic levels

Examples: Discuss the following statements

- C_6H_{14} is hexane

- Nylon is a long molecule

- In an oxidation reaction zinc loses electrons

- Hydrogen is the smallest element

COMMUNICATION EXERCISE 1

The following table provides information about 0.100 mol L^{-1} solutions of ammonia, ammonium nitrate and nitric acid.

Account for the variation in properties

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

Property	Species	Link

PROBLEM SOLVING and CALCULATIONS

"PROBLEM SOLVING is what you do when you don't know what to do"

Critical thinking and pr oblem solving– not the same as using previously memorised procedures (although these might be used to solve the problem)

1. Define the problem

What aspects of chemistry are involved in this problem

What is known about the problem?

What do we need to know in order to solve the problem?

Are there any constraints (assumptions, limits etc)?

What are the criteria for success? – What will a logical answer look like? (Units etc)

2. Plan a Solution

3. Reflect on your answer

Does the answer make sense?

Does it fit with the criteria established in step 1?

Did I answer the question(s)?

(What did I learn by doing this? Could I have done the problem another way?)

PROBLEM SOLVING/CALCULATIONS

"PROBLEM SOLVING is what you do when you don't know what to do"

Suggestions:

1. Read the **whole** problem carefully. Identify what the problem is asking (make sure that you answer this!)
2. Find a way of 'unpacking the question' e.g. identify key pieces of information / extra information given that is not needed – possibly draw a flow chart/write equations
3. Link important information to the processes or species discussed e.g. identify key observations e.g. colour, state or identify key reactions: oxidation – reduction, acid – base, precipitation

For calculations:

- Make a list of the knowns and unknowns and identify a path to get from what is given to what is asked for.
- Check your answer and make sure that it is reasonable.

Remember: Whenever you solve a numerical problem think about what the numbers actually represent on the molecular level i.e. in terms of atoms and molecules.
Include units in your working as this confirms the correct equations

PROBLEM SOLVING 1 (SCHOLARSHIP 2010)

Five elements designated as **V, W, X, Y, Z** have the following properties. Note that the letters bear no relationship to the symbols of the elements.

- Elements **V** and **Z** have the same number of valence electrons
- The molar mass of the elemental form of element **V** is 2.00 g mol^{-1}
- Element **W** is the most reactive of its group which only contains non-metals
- The valence electrons of elements **X, Y** and **Z** are in the same energy level
- Element **Y** has a lower first ionisation energy than element **X**
- Elements **Z** and **Y** react to form the compound Z_2Y which dissolves in water to give a basic solution than conducts electricity
- Elements **V** reacts with element **X** to form XV_3, a poisonous gas
- The ions of elements **W** and **Z** have the same total number of electrons
- Element **V** reacts with element **W** to form **VW**, a gas at 25 °C.
- Element **V** reacts with element **Z** to form **ZV**, and ionic solid.

Identify each of the elements **V, W, X, Y** and **Z.** Justify your answer.

PROBLEM SOLVING 2

- Chamomile is a plant of the sunflower family and has been used as a homeopathic medicine for thousands of years. It is often used to treat symptoms related to sleep disorders, digestion conditions, cramps, skin infections, inflammation and teething pains. The main compound in chamomile that is responsible for its anti-inflammatory properties is α-bisabolol.
- A 6X chamomile remedy recommends that adults take a 1 mL dose. How many α-bisabolol molecules are present in each 1 mL dose.

INFORMATION:

- A 6X homeopathic medicine means that a 1-to-10 dilution has been carried out 6 times leaving the active ingredient diluted to 1 millionth of its original concentration
- The density of chamomile is 0.91 g mL^{-1}
- α-bisabolol is $C_{15}H_{26}O$ and has a molar mass of 222.4 g mol^{-1}
- Chamomile is a mixture of many compounds. Assume that 0.25% of the mass of chamomile is α-bisabolol.

REDOX TITRATIONS

- Titrations can be performed for any reaction that goes to completion provided that the end-point can be observed. Redox reactions are often convenient in analysis because the appearance or disappearance of a colour related to an ion is an ideal criterion for the end-point of the reaction.
  e.g. $6H^+ + 2MnO_4^- + 5(COOH)_2 \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$
- Iodine is widely used as a reagent for the volumetric determination of strong reductants such as thiosulfate ($S_2O_3^{2-}$). A starch indicator will determine the end point as it is blue in the presence of iodine.
  Neither iodine nor sodium thiosulfate are suitable as primary standards. However, potassium iodate is a powerful oxidising reagent and a 'good' primary standard. Standard 'iodine' solutions can be prepared from potassium iodate via the reaction: $IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$
  The liberated iodine is titrated with sodium thiosulfate.

$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$

$S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$

$(6S_2O_3^{2-} + 3I_2 \rightarrow 3S_4O_6^{2-} + 6I^-)$

Overall: $IO_3^- + 6S_2O_3^{2} + 6H^+ \rightarrow 3S_4O_6^{2-} + 3I_2 + 3H_2O$

REDOX TITRATION PROBLEM 1 (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 the bottle of household bleach.

A 20.00 mL sample of the bleach is diluted to 250.00 mL, using a volumetric flask. Excess potassium iodide is added to a 10.00 mL sample of the 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.

$2S_2O_3^{2-} + I_2 \rightarrow 2I^- + S_4O_6^{2-}$

The titration data is given below. Determine the extent of the decomposition of the bleach by comparing the available chlorine (% m/V) in the bottle, with that given on the label.

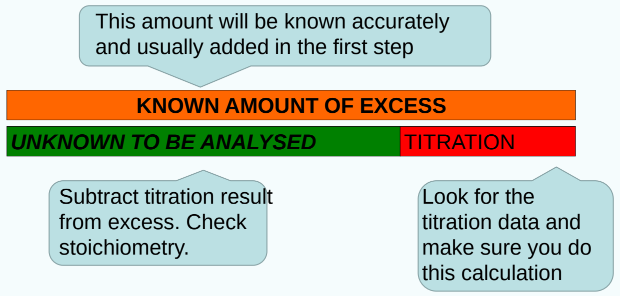
Titre	Final volume /mL	Initial volume /mL
1	16.88	0.16
2	33.56	16.88
3	16.98	0.02
4	33.64	16.98

REDOX TITRATION PROBLEM 2 (SCHOLARSHIP 2016)

- Iron ore, Fe_2O_3, in a rock sample can be analysed by titration with acidified potassium dichromate solution K_2CrO_7/H^+. A 2.8351 g sample of haematite rock containing Fe_2O_3, was dissolved in hot concentrated hydrochloric acid, HCl, and the solution diluted to 250.0 mL in a volumetric flask.
- 20.00 mL samples were pipetted into conical flasks, and a small excess of tin(II) chloride solution was added to change the colour from yellow to pale green. A saturated solution of mercury(II) chloride was then added until a small amount of white precipitate appeared. A few drops of diphenylamine sulfonate indicator were added. The resulting mixture was titrated with a standard solution of potassium dichromate. The average titre value recorded was 18.56 mL.
- The standard solution of potassium dichromate was made by dissolving 2.5077 g of $K_2Cr_2O_7$ in sufficient water to give 500.0 mL of solution.
- Calculate the % composition of Fe_2O_3 in the haematite sample.

BACK TITRATION

- Used when reactions are slow OR there are competing reactions OR the is no easy way to detect the end point
- A measured amount of reagent is added all at once (more than is needed to completely react with the sample)
- When reaction is complete the amount of unreacted reagent (excess) is determined using a standard solution



TITRATION PROBLEM 2

25.00 mL of 0.100 mol L^{-1} NaOH were added to 10.00 mL of a solution of NH_4Cl. The volume was diluted to about 150 mL and then gently boiled till no more ammonia was evolved. The solution was cooled and then the amount of unreacted NaOH was measured by titrating against H_2SO_4. 15.50 mL of 0.0521 mol L^{-1} H_2SO_4 were required for complete reaction.

Calculate the concentration of the NH_4Cl solution

KNOWN AMOUNT OF EXCESS	
UNKNOWN TO BE ANALYSED	TITRATION

PROBLEM SOLVING 3 (SCHOLARSHIP 2009)

15.35 g of a mixture of sodium nitrate, $NaNO_3$, and magnesium nitrate, $Mg(NO_3)_2$, was heated until no more gases were evolved. The $NaNO_3$ decomposes giving $NaNO_2$ and oxygen gas, while the $Mg(NO_3)_2$ decomposes to give the metal oxide, NO_2 and oxygen. The water soluble part of the residue produced on heating was used to prepare a 1.00 L solution. 10.00 mL of this solution was reacted with 20.00 mL of acidified $KMnO_4$ (which oxidises NO_2^- to NO_3^-). The excess potassium permanganate required 10.25 mL of 0.0500 mol L^{-1} oxalic acid, $H_2C_2O_4$, for complete reaction in which CO_2 is produced.

Write balanced equations for all the reactions and calculate the mass, in grams, of each metal nitrate present in the original mixture.