Interdisciplinary Science

PA1012

Science of the Invisible

University of Leicester

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Welcome

In *Science of the Invisible* you will explore the structure of microscopic objects from cells to molecules to atoms. At the smallest scale the world is governed by quantum mechanics which controls the properties of atoms and their binding to form molecules. You will also learn about the states of matter, gases liquids and solids, and how their properties arise from the properties of their constituents.

Module Authors

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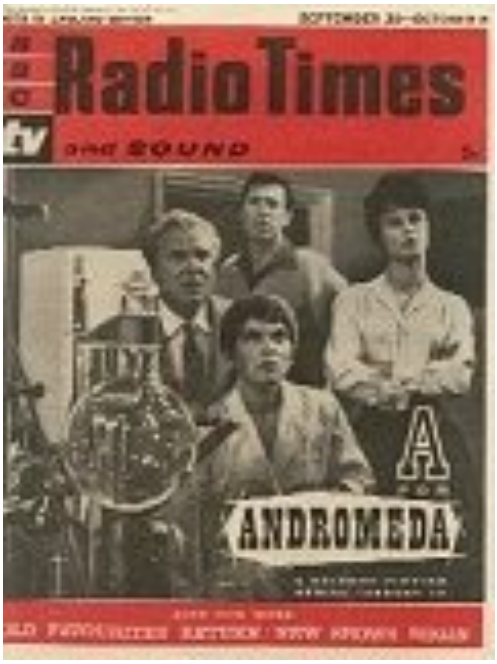
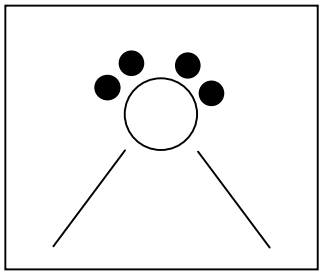
Problem Statement

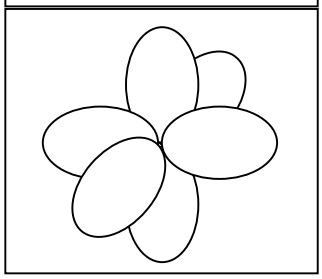


A for Andromeda was a made-for-TV Science Fiction serial broadcast in 1961. The basic plot is the discovery of a radio message received from a distant civilisation with coded instructions on how to make a living being. Unfortunately the tapes of all but one of the episodes have been wiped so the coded message has been lost. In order to advertise their remake of the series **TV Remakes Unlimited** decided to publicise the supposed discovery of a "real" coded message received by Jodrell Bank in 1987 which it claimed had been hushed up by the military and government. The code in the original broadcast production was alpha-numeric but it was decided to give the supposedly newly discovered one a hieroglyphic form to make the deciphering more interesting.

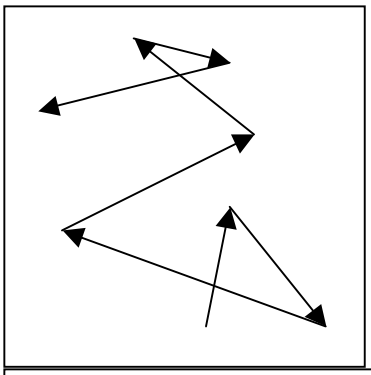
You must decide what *each* hieroglyph symbolises and therefore in which order the "message" should be assembled in order to create the life form.



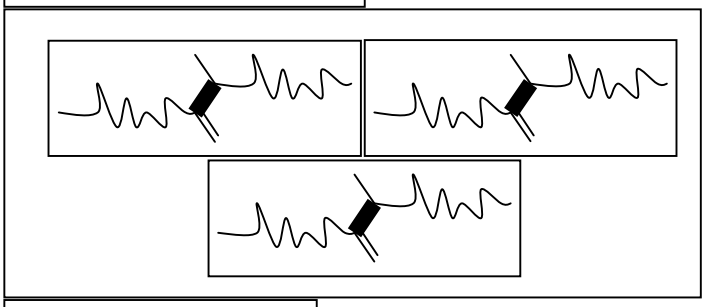
A Water Molecule



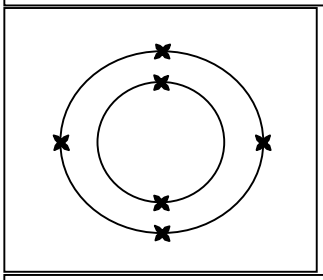
B Atomic Orbitals (p)
The Electron



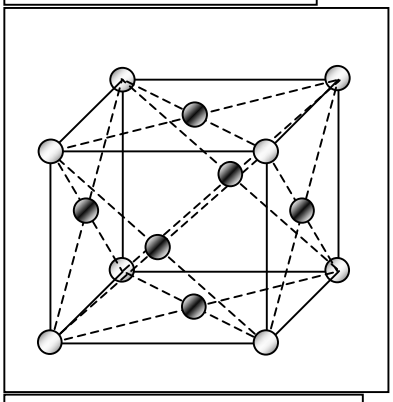
C Random Motion of Gas Particles



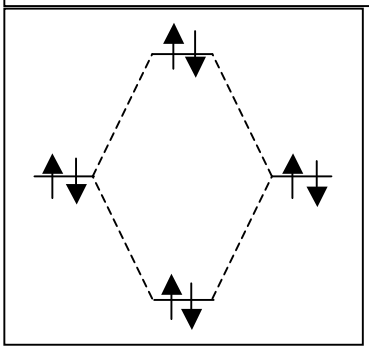
D Amino Acids and Proteins



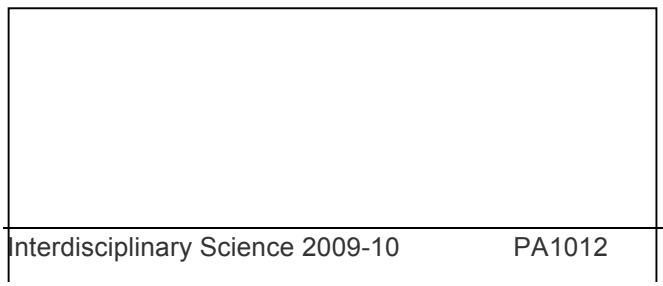
E Carbon Atom



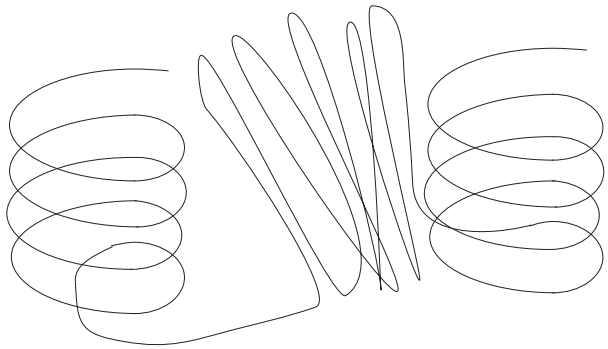
F Solid Crystal Lattice

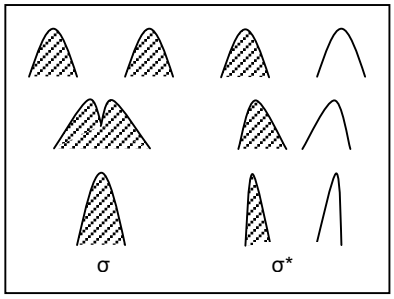


G Molecular Orbitals

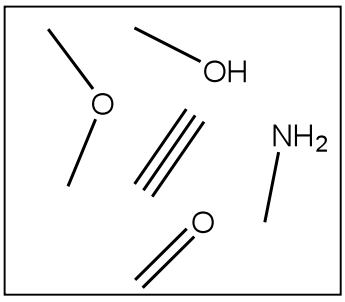


H Alpha Helix and Beta Sheets (Protein Structure)

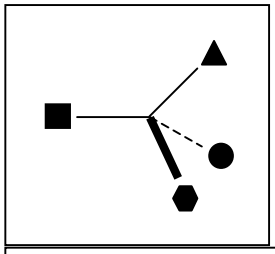




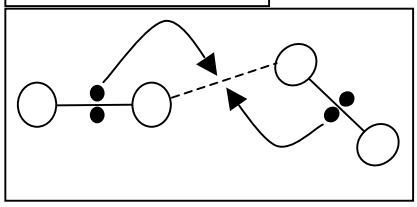
I Wavefunction Interference



J Functional Groups



K Chiral Carbon



L Chemical Bond Formation

sp^3

M Hybridisation

Staff

Prof Derek Raine	Physics
Dr Dylan Williams	Chemistry
Dr Dai Davies	Chemistry
Dr Tim Harrison	Biochemistry
Dr Cory Evans	Chemistry
Dr Andrew Ellis	Chemistry
Dr Karl Ryder	Chemistry

Learning Objectives

- Atomic Structure
  Electron spin, Orbitals, The Pauli Principle, The Aufbau Principle, Hund's Rules.
- Bonding
  Formation of molecular orbitals, Shapes and energies of orbitals, Antibonding orbitals, Covalent Bonding, Sigma and Pi bonds.
- Shapes of Molecules
  Valence Shell Electron Pair Repulsion Theory (VSPERR)
- Introduction to Organic Chemistry
  Basic structure of organic molecules, Isomerism, Functional Groups.
- Steroisomerism
  Chiral centres, Enantiometers, Optical rotation and activity, Racemic mixtures, Polarimetry.
- Amino acids and proteins
  Peptide bond formation, Nature and effect of side chains, Primary, Secondary, Tertiary and Quaternary protein structure, Biochemical roles of proteins.
- Fats
  Chemical structure of fats, Biochemical role of fats.
- Carbohydrates
  Chemical structure of carbohydrates, Biochemical role of carbohydrates.
- DNA
  Chemical structure of DNA and its component parts, Biochemical roles of DNA.
- Representation versus reality
  Methods of representing atoms and molecules, Pros and cons of different representations, Application of different representations.
- Gases
  Kinetic theory of gases, Collisions, Mean free path, Concept of degrees of freedom – translational, rotational and vibrational motion.
- Solids
  Types of solid structure: Metallic solids, Ionic solids, Network solids, Amorphous solids.
- Liquids
  Intermolecular forces, The structure of liquids.
- Water and Equilibrium
  Dynamic equilibria, Equilibrium constants, Chemical equilibria, The ionic product of water.
- Solutions
  Solubility and solutions, Dissociation, Electrolytes, Molarity and concentration.
- Acids and Bases
  Acid and base equilibrium, Strong and weak acids, pKa and pH.

Reading List

Main list

- Brown, T.L., LeMay, H.E. & Bursten, E.B. (2003) *Chemistry: The Central Science: 9th Ed*. Prentice Hall.
- Campbell, N.A. & Reece, J.B. (2005) *Biology: 7th Ed*. Pearson.
- Housecroft, C.E & Constable, E.C (2001) *Chemistry: An Introduction to Organic, Inorganic and Physical Chemistry: 2nd Ed*. Prentice Hall.
- Sutton, J (1998) *Biology*, pp 39-123. Macmillan Foundations.
- Zumdahl, S.S. (2007) *Chemical Principles: 6th Ed*. Houghton Mifflin.

Additional books

- Breithhaupt, J. (2003) Physics: 2nd Ed. Palgrave Foundations.
- Lewis, R. & Evans, W. (2006) *Chemistry: 3rd Ed*. Palgrave Foundations.

Facilitation Sessions

Facilitation Session 01

Pre Session Preparation

Read the Problem Statement

Group Discussion: Scale

The hieroglyphs come in a variety of scales. You will need to find out numerically what these are. To display the result you need a basic unit and a factor by which the object represented by the hieroglyph is larger or smaller than the basic unit. But it would be useful for the web site if the basic unit were not fixed, but could be freely specified by the user. You will be asked to write an excel spreadsheet to do this i.e. to allow the user to find out how much smaller or larger a given object is than a reference object of their choice.

Your spreadsheet should be included with your report.

Expectations for the next session

Read:

- ZUM: Chapter 2 (scale)
- Biology (Sutton): p 64-86

Facilitation Session 02

Scale and Cell Structure

Pre Session Preparation

Read:

- ZUM: Chapter 2 (scale)
- Biology (Sutton): p 64-86

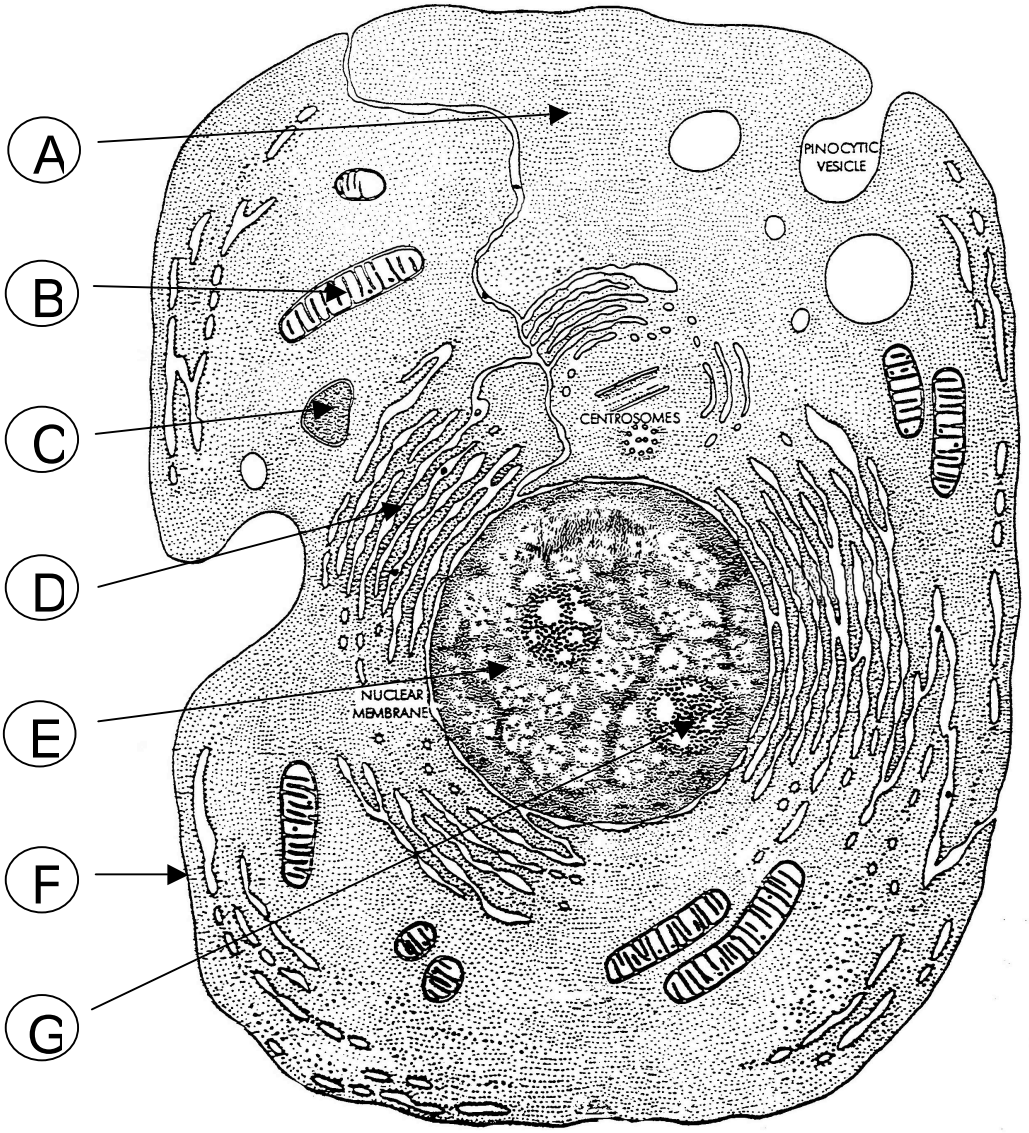
Group Discussion: Cell structure

What is in a cell? That's a huge question for such a tiny object! You will need to produce a clear diagram of a cell; we have made this easy for you by providing an unlabelled cell. (see Supplementary Materials "Cell Structure: Diagram and Tables").

The diagram following shows a typical mammalian cell with seven unidentified structures (A-G). Below are lists of cellular structures and functions associated with those structures. Using these lists, fill in the associated table.

STRUCTURES	FUNCTIONS
Cytoplasm	Cellular digestion
Golgi complex	Cellular respiration
Lysosome	Cell morphology & movement
Mitochondrion	DNA synthesis
Nucleolus	Detoxification reactions
Nucleus	Export of proteins
Plasma Membrane	Energy conservation
	Membrane synthesis
	Metabolism of carbohydrates, lipids, amino acids and nucleotides
	Protein synthesis
	RNA synthesis
	RNA processing and ribosome assembly
	Transport of ions and molecules

	STRUCTURE	FUNCTION(S)
A		
B		
C		
D		
E		
F		
G		



Expectations for the next session:

- ZUM: p 510-544
- BLMB: p 36-48 (general), p 47-80 (detail)
- HOUSE: (detail)
- ZUM: p 566-598.
- BLMB: p 274-299 (general)
- HOUSE: p 134-162 (advanced)

Facilitation Session 03

Atomic Structure and Bonding

Pre Session Preparation

Read:

- ZUM: p 510-544
- BLMB: p 36-48 (general), p 47-80 (detail)
- HOUSE: (detail)
- ZUM: p 566-598.
- BLMB: p 274-299 (general)
- HOUSE: p 134-162 (advanced)

Group Discussion: Atomic structure

Before the expert session on atomic structure, the students should try to pool their existing knowledge about the structure of atoms. They are likely to know quite different amounts, depending on their backgrounds. Some questions that might be put to them to provoke thought are;

- What are protons, neutrons and electrons and where would one find them within an atom?
- What are the properties (charge and mass) of protons, neutrons and electrons?
- How is an atomic nucleus composed?
- How are the electrons arranged in a hydrogen atom? How about a nitrogen atom and a chromium atom?
- Why do the noble gases exist as atoms but nitrogen exists as molecules?
- What does atomic number refer to? How about mass number?
- What are isotopes?
- What is an orbital?

Group Discussion: Bonding

Molecules are formed from atoms but how and why? Here are some problems for you to consider before the bonding expert session.

- Why do the noble gases exist as atoms, but hydrogen and nitrogen exist as molecules?
- What is an ion?
- Why do some atoms prefer to form ions and some atoms prefer to form molecules?
- What is electronegativity?
- In a molecule of HCl, where do the bonding electrons spend more of their time?
- What is a sigma (σ) bond? How about a pi (π) bond?

- What is an antibonding orbital?

Expectations for the next session:

- ZUM: p 609-619
- BLMB: p 318-328
- HOUSE: p 134-162 (advanced)

Facilitation Session 04

Shapes of Molecules

Pre Session Preparation

Read

- ZUM: p 609-619
- BLMB: p 318-328
- HOUSE: p 134-162 (advanced)

Group Discussion: Shapes of Molecules and VSPERR

End of week discussion:

End of week discussion on the work covered so far. Can the students identify any new hieroglyphs, or have they changed their minds above previous choices?

Expectations for the next session:

- ZUM: p 971-985, p 985-992
- BLMB: p 982-1009
- HOUSE: p 736-749

- ZUM: p 909-916
- BLMB: p 1009-1001
- HOUSE: p752-762

Facilitation Session 05

Organic Chemistry and Steroisomerism

Pre Session Preparation

Read:

- ZUM: p 971-985, p 985-992
- BLMB: p 982-1009
- HOUSE: p 736-749
- ZUM: p 909-916
- BLMB: p 1009-1001
- HOUSE: p 752-762

Introduction to Organic Chemistry:

The next two days are going to be concerned with the structure, shape and representation of organic molecules. These are molecules based on carbon skeletons i.e. they are made up of frameworks assembled primarily from carbon atoms. They are of massive importance because all of the biological molecules on the planet are molecules of this kind.

Expectations for the next session:

- ZUM: p 1009-1021
- BLMB: p 1012 (amino acids), p1013-1016 (proteins)
- HOUSE: p 1065-1068 (amino acids), p 1074-1078 (proteins)

Facilitation Session 06

Proteins

Pre Session Preparation

Read:

- ZUM: p 1009-1021
- BLMB: p 1012 (amino acids), p1013-1016 (proteins)
- HOUSE: p 1065-1068 (amino acids), p 1074-1078 (proteins)

Group Discussion: Proteins

- What happens to protein when we eat it?
- Why do we need protein in the diet?
- What are typical functions of proteins in the body?
- What is an essential amino acid?

Expectations for the next session:

- ZUM: p 1029-1034
- BLMB: -
- HOUSE: p 1027
- ZUM: p 1021-1025
- BLMB: p 1017-1020
- HOUSE: p 1056-1065

Facilitation Session 07

Fats and Carbohydrates

Pre Session Preparation

Read

- ZUM: p 1029-1034
- HOUSE: p 1027
- ZUM: p 1021-1025
- BLMB: p 1017-1020
- HOUSE: p 1056-1065

Group Discussion: Fats and Carbohydrates

Some questions for thinking about carbohydrates:

- What is a monosaccharide?
- What is a disaccharide?
- What is a polysaccharide?
- What happens to carbohydrate after it is eaten?
- Why are sugars needed by cells?

Some questions for thinking about fats:

- The major components of dietary fats are triglycerides (triacylglycerols). What are these?
- How are the components of fat used in cells?
- What is an essential fatty acid. Why is it important?
- What are phospholipids?

Expectations for the next session:

- ZUM: p 1025-1029
- BLMB: p 1020-1025
- HOUSE: p 1078-1083

Facilitation Session 08

DNA

Pre Session Preparation

Read:

- ZUM: p 1025-1029
- BLMB: p 1020-1025
- HOUSE: p 1078-1083

Group Discussion: DNA

Some questions for discussion about DNA:

- What is a helix? How about a double helix?
- What are the parameters that describe the appearance of a helix? This will be important for the animators.
- What makes up the backbone of DNA?
- How are the two strands of DNA connected together?
- What are base pairs and how are they connected to the rest of the DNA molecule?
- What is a polynucleotide?
- How long are typical strands of DNA?
- If you found DNA in a cell, how might it appear?
- What are some of the functions of nucleic acids in cells?
- What happens to nucleic acids after they are eaten?
- Why aren't nucleic acids or nucleotides essential in the diet?

End of week discussion:

End of week discussion on the work covered so far. Can the students identify any new hieroglyphs, or have they changed their minds above previous choices?

Expectations for the next session:

- Reflect on the type of representation seen so far.

Facilitation Session 09

Representation versus Reality

Group Discussion: Representation versus reality

Discuss the different ways in which scientists represent molecules and the advantages and disadvantages of these various approaches. How close each of the pictures comes to representing what molecules actually look like?

The most likely representations you will come across are:

- carbon skeletons
- 3D organic representations involving
- Hard spheres
- Ball and stick models
- Space filling models
- Electron density maps
- Fisher projections
- Dot and cross diagrams

Look in some detail into why the particular representations are used, when they are at their most and least useful and how close they come to reality.

Expectations for the next session:

- ZUM: p 152-169
- BLMB: p 386-393
- HOUSE: p 14-15

Facilitation Session 10

Gases

Pre Session Preparation

Read:

- ZUM: p 152-169
- BLMB: p 386-393
- HOUSE: p 14-15

Group Discussion: Gases

Use the following questions to open up a discussion:

- What molecules are in the air we breathe? What are the five most common species?
- Can you estimate the average molecular speed of the nitrogen molecules in the facilitation room?
- Do all the molecular species move at the same speed?
- How often do the molecules in the air collide? How far do they travel, on average, between collisions?

Expectations for the next session:

- ZUM: p 735-762
- BLMB: p 427-441
- HOUSE: p 238-248, 269-271, 279-287

Facilitation Session 11

Solids

Pre Session Preparation

Read:

- ZUM: p 735-762
- BLMB: p 427-441
- HOUSE: p 238-248, 269-271, 279-287

Group Discussion: Solids

Describe the different types of solid that exist, what their molecular structure is and to indicate why particular structures are formed.

The main types of solid that the students should discover and include information on are:

- Metallic solids
- Ionic solids
- Molecular solids
- Networks solids
- Polymeric solids

Expectations for the next session:

- ZUM: 729-735
- BLMB: p 408-427

Facilitation Session 12

Liquids

Pre Session Preparation

Read:

- ZUM: 729-735
- BLMB: p 408-427

Group Discussion: Liquids

Why is water a liquid?

- What is a liquid?
- What makes something a solid, a liquid or a gas?
- What are the differences in the forces between particles in a solid, a liquid and a gas?
- Why does water form a liquid when some bigger and heavier molecules do not (e.g. hydrogen sulphide, carbon dioxide)?

End of week discussion:

End of week discussion on the work covered so far. Can the students identify any new hieroglyphs, or have they changed their minds above previous choices?

Expectations for the next session:

- ZUM: p 227-228, 629-631
- BLMB: p 620
- HOUSE: -
- ZUM: p 188-215
- BLMB: p 574-604
- HOUSE: p 440-462

Facilitation Session 13

Water and Equilibrium

Pre Session Preparation

Read:

- ZUM: p 227-228, 629-631
- BLMB: p 620
- ZUM: p 188-215
- BLMB: p 574-604
- HOUSE: p 440-462

Group Discussion: Water and Equilibrium

Expectations for the next session:

- ZUM: p 87-98
- BLMB: p 112-117, 134-140

Facilitation Session 14

Solutions

Pre Session Preparation

Read:

- ZUM: p 87-98
- BLMB: p 112-117, 134-140

Group Discussion: Solutions

Example questions regarding salt dissolved in water;

- How does salt dissolve in water?
- When it has dissolved, what species are present?
- Is there any effect of these species on the surrounding water molecules?
- What is the concentration and how is it calculated?
- How many ions are there present relative to water molecules?

Expectations for the next session:

- ZUM: 223-238
- BLMB: p 612-636
- HOUSE: p 448-462

Facilitation Session 15

Acids and Bases

Pre Session Preparation

Read:

- ZUM: 223-238
- BLMB: p 612-636
- HOUSE: p 448-462

Read the laboratory notes in preparation for laboratory titration.
Come to the session prepared to discuss:

- **Acids and Bases:** Acid and base equilibrium, Strong and weak acids, pKa and pH.

Group Discussion: Acids and Bases

Facilitation Session 16

Recap and Consolidate

Pre Session Preparation

Bring drafts of your deliverables to the session

Group Task: Final Preparations and Questions

This session should be used to recap the information covered in the module, answer any final questions and to ensure that the students are on track to hand in their Deliverable.

Deliverables

Please name your deliverables in accordance with the standard naming convention (see the handbook for details). A sample filename is provided for you to cut and paste - please complete with submission date and username/group letter as appropriate.

All deliverables to be submitted to the subject centre.

Please note that although deliverable deadlines (except for CLEs) are at the end of the module, you are strongly urged not to leave all work on the deliverables until the final weekend! In particular, if you would like formative feedback on your works-in-progress from your facilitator and/or experts, please provide them with draft copies in good time.

DELIVERABLES	TYPE	FILENAME	DUE	WEIGHTING
CLE01: Size and Scale	I	PA1012_I_CLE01_*username*_*date*.pdf	Week 2, Day 1	7.5%
CLE02: Bonding	I	PA1012_I_CLE02_*username*_*date*.pdf	Week 3, Day 1	7.5%
CLE03: Biopolymers	I	PA1012_I_CLE03_*username*_*date*.pdf	Week 4, Day 1	7.5%
CLE04: Intermolecular Forces	I	PA1012_I_CLE04_*username*_*date*.pdf	Week 5, Day 1	7.5%
D01: Report	G	PA1012_G_D01_Report_*groupletter_date*.pdf	Week 5, Day 3	70.0%

Core Learning Exercise 01: Size and Scale

1. An architect wishes to make a one-hundredth scale model of the new St. Pancras Station. All answers should be express in Standard International units, and using scientific notation, ('standard' or 'exponential' form).

   (a) The Champagne bar measures 90 m in length. How long will the champagne bar be in the model? [1]

   (b) Twenty thousand litres of blue paint were used to paint St. Pancras station. How many litres will be needed to paint the model? [2]

   (c) A Gastro pub has replaced the old Mc Donalds. In the model, the Gastro pub has a volume of 4.56×10^{-3} m^3. If the minimum requirement for space is 8 m^3 per person, how many people will be allowed in the St. Pancras Gastro pub? [3]

2. Give the Standard International (SI) unit and its abbreviation for each of the following:

   (a) Mass
   (b) Length
   (c) Time
   (d) Temperature
   (e) Amount of substance
   (f) Electric current
   (g) Energy
   (h) Luminous intensity [4]

3. Convert the following measurements into the units given in brackets. Give your answers in both 'everyday' form and in exponential form.

   (a) 6.35×10^{-2} L (cL)
   (b) 3.5×10^{-10} g (ng)
   (c) 6.54×10^{9} fs (μs)
   (d) 150 mL(L)
   (e) 3.4 kJ (J)
   (f) 25 ºC (K)
   (g) 2.4 km (nm) [4]

4. Say which of the following is bigger, and by what multiple?

   (a) 2.4 cm or 0.24 m
   (b) 1200 mg or 1.2×10^{4} μg
   (c) 3.5×10^{5} fs or 3.5 ms
   (d) 75 cL or 7.5×10^{-2} L [4]

5. Give the three main types of fibres that make up the cytoskeleton. For each type, *describe* two main functions. [6]

6. (a) Describe the difference in function between the cis- and trans- face of the Golgi apparatus. [2]

(b) How is this function difference reflected in the location of the Golgi apparatus with respect to other cell organelles? [1]

7. Describe the structural and functional distinctions between rough and smooth endoplasmic reticulum. [2]

8. Draw a short cartoon strip, with 3 – 5 captioned pictures to show the process of phagocytosis. [3]

9. (a) Describe two significant similarities and two differences between chloroplasts and mitochondria. [4]

(b) Explain the characteristics of mitochondria and chloroplasts that place them in a separate category from organelles in the endomembrane system. [2]

10. (a) Where is ribosomal RNA synthesised? [1]

(b) What other type of macromolecule is required to make ribosomes? [1]

11. Draw a cartoon strip which describes what happens within the nucleus as the cell divides during mitosis. You may use words and/or diagrams in your answer. [5]

12. (a) Draw a diagram of a cell membrane, labelling the hydrophilic and hydrophobic parts of the lipid bilayer, and include a channel protein in your diagram [2]

(b) Describe how aquaporins assist the transport of water molecules across the cell membrane. [2]

(c) Briefly describe the discovery of aquaporin and relate it to the maxim ‘chance favours the prepared mind’. [2]

13. Describe the difference between passive transport and active transport across a cell membrane and give an example of each. [2]

14. (a) Give the relative intra- and extra- cellular concentrations of sodium and potassium ions in a nerve cell. [1]

(b) When nerve cells establish a voltage across their membrane with a sodium-potassium pump, does this pump use ATP or ADP? Why? [1]

(c) Describe whether each of the ions above are actively or passively transported. [1]

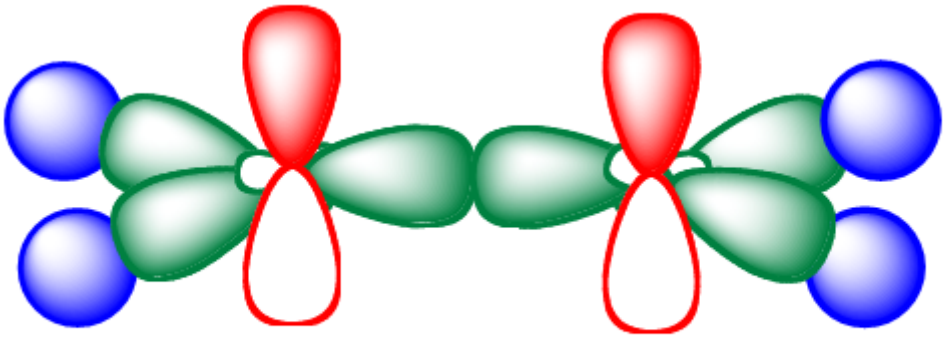
(d) Could this process be considered co-transport? Explain. [1]

[Total Marks 57]

Core Learning Exercise 02: Bonding

1. The configuration of electrons surrounding an atoms nucleus will affect its chemical and physical properties. In any atom, the electrons are arranged in different valence shells and orbitals. Sketch the shapes of s, p, and d orbitals. [3]

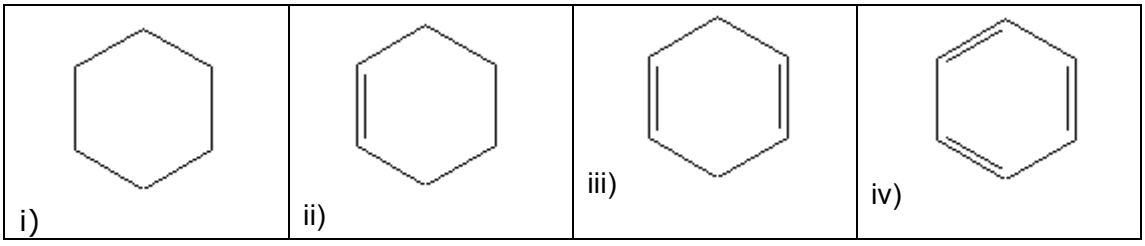
2. Given below is the bonding orbital diagram of an **ethene** ($H_2C=CH_2$) molecule. Label the **σ and π bond.** (Blue = s, green = Sp^3 orbital, red p orbital). [2]



3. Aromatic compounds are important in chemistry and biology since they are found in many naturally occurring molecules. The Huckel 4n + 2 π rule determines whether a compound is aromatic or not.

   (a) Benzene is an example of an aromatic hydrocarbon. How many C-C π bonds are present in benzene? [1]

   (b) Which of the following molecules is identified as an aromatic hydrocarbon? [1]



4. The ground state electron configurations of elements are important to chemists. Explain what is meant by the ground state electron configuration and which rules are important in building up this picture, using carbon as an example. [5]

5. Give the ground state electron configurations of:
   (a) Carbon [1]
   (b) Neon [1]

6. The molecular orbital theory goes a long way in explaining why some molecules exist (e.g. H_2) and why some do not (e.g. He_2).

(a) Explain what is meant by M.O theory using the following terms:

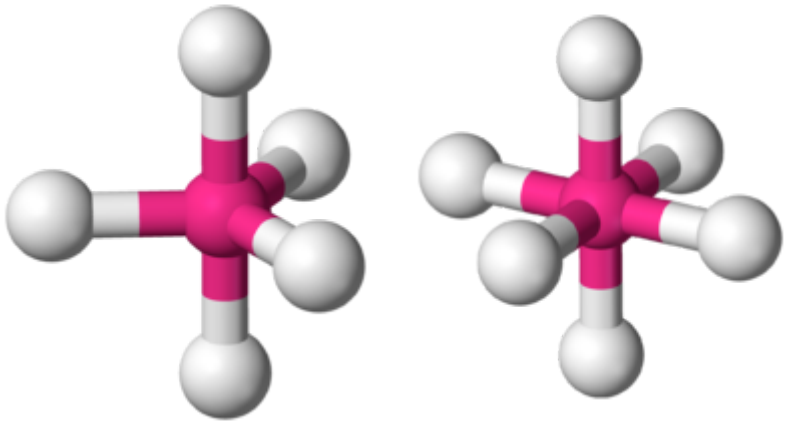
Bonding M.O, antibonding M.O [4]

(b) Draw and label a simple molecular orbital diagram for a H_2 molecule. [1]

(c) By reference to the molecular orbital diagram, explain why He_2 is unstable. [1]

Shapes

7. Give the bond angles present in each of the molecules below. [1]



8. VSEPR theory provides a simple model for predicting the shapes of species.

(a) Define what VSEPR stands for. [1]

(b) Show that VSEPR theory is in agreement with the following molecular shapes:

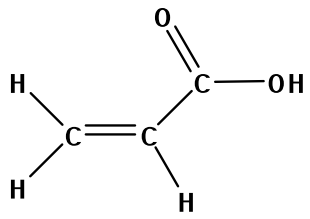
BCl_3 → trigonal planar
$[IF_5]^{2-}$ → pentagonal planar
$[NH_4]^+$ → tetrahedral
SF_6 → octahedral [4]

(c) Using VSEPR theory, determine the shape of the following molecules: $BeCl_2$, NH_3, PF_5
[3]

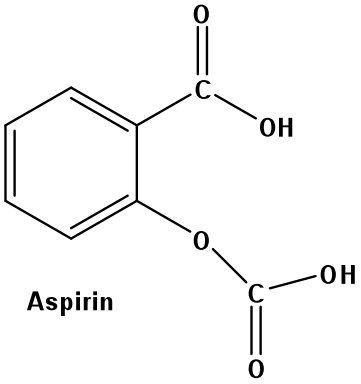
(d) Hence, deduce the names of shapes given to each of the above molecules. [3]

Functional Groups

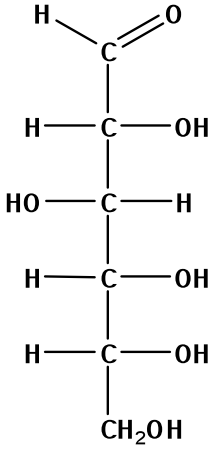
9. Circle and identify the functional groups in the following molecules:



Acrylic acid



Aspirin



Glucose

[3]

10. Organic chemists working in the pharmaceutical industry need to know how to synthesise molecules with different functional groups on the active molecules. Below is a list of common functional groups used in pharmaceutical drugs. Draw these functional groups and give an example of each.

    (a) Alcohol
    (b) Ether
    (c) Aldehyde
    (d) Ketone
    (e) Carboxylic Acid
    (f) Ester
    (g) Amine [7]

Stereochemistry

11. Consider the molecule with the condensed structural formula $C_2H_5CH(OH)CH_3$.
    (a) Name the molecule [1]
    (b) Draw a carbon skeleton representation of the molecule and identify the chiral carbon. [1]

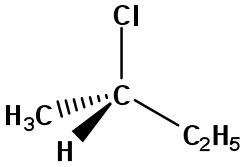
12. Give 3 isomers of C_3H_8O, naming each respective structure according to IUPAC notation. [3]

13. Name the 3 different classes of structural isomers, giving an example in each case. [3]

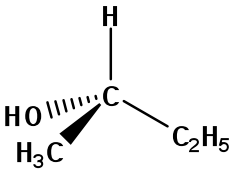
14. Determine which of the following compounds will be chiral. If chiral identify the stereogenic centre.
    (a) 2-Bromopentane
    (b) 4-Heptanol
    (c) 2-methyl-1-butanol
    (d) 1-chloro-2-methylbutane
    (e) 2-propanol [5]

15. Enantiomers can be distinguished via there configuration, hence assign R,S configurations to the following molecules. (You may use molecular models to help you).

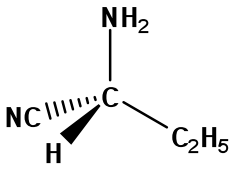
[3]



A



B



C

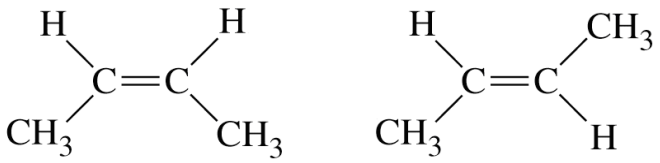
16. (a) Draw and label a systematic representation of a polarimeter. [2]

(b) With reference to the above diagram. Explain how optically active molecules can be distinguished via the above technique. [2]

[Total marks 62]

Core Learning Exercise 03: Biopolymers

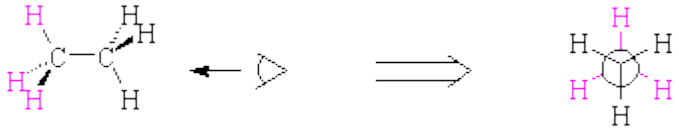
1. Alkenes exist as geometrical isomers due to restricted rotation about the C-C double bond. They have different physical and chemical properties and are therefore separable. In the pharmaceutical industry this can mean the difference between a drug curing or killing a patient. State, with reasons, which of these geometrical isomers has the lowest energy conformation.



[2]

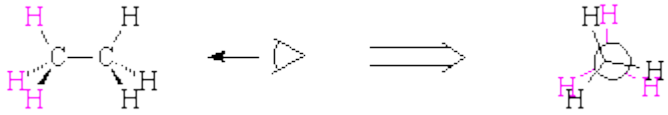
2. When organic chemists try to predict a mechanism for a reaction, the conformation of the reactant species might be of importance. This is due to the fact that during nucleophilic attack, the nucleophile will prefer to attack the reactant in its lowest energy conformation. Using ethane as an example explain which of these has the lowest conformation?

(a)



or

(b)



[2]

3. Haemoglobin is an important biological transporter of oxygen. It is a protein consisting of four subunits, which alters its conformation slightly depending on the partial pressure of oxygen, and in so doing, allows the reversible bonding of oxygen to it. By reference to the molecule haemoglobin, describe the primary, secondary, tertiary and quaternary structure of proteins. [2]

4. Consider that you have just eaten a Big Mac meal, consisting of a Big Mac burger, fries, tomato sauce and a drink of sprite. (Note: this course of action is not endorsed in any way by the I-Science department!).

   Decide whereabouts in the above meal you would find each of the following:

   (a) A monosaccharide
   (b) A polysaccharide
   (c) Cellulose

(d) Protein
(e) Lipids [2]

5. A region along one DNA strand has this sequence of nitrogenous bases:

5' – TAGGCCT – 3'.

(a) Draw a structure for this DNA strand which shows how the phosphates and sugars are connected to the first three bases TAG. [1]

(b) List the base sequence along the other strand of the molecule, clearly indicating the 5' and 3' ends. [1]

(c) Write a flow chart to show how a strand of DNA codes for a length of polypeptide. [4]

6. Consider the molecule ethanol. Using the program chem draw to help you (this is CFS software), give the following structures for ethanol:

(a) A condensed structural formula
(b) A carbon skeleton

(c) A representation of the molecule in 3-dimensions

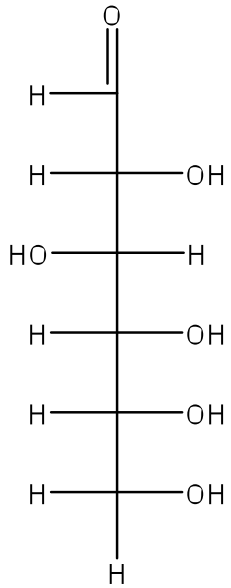
(d) A dot and cross diagram of the molecule

(e) A space filling model [6]

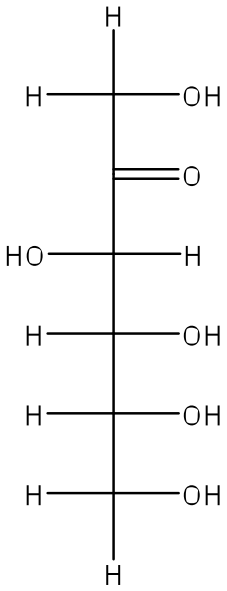
7. Different representations of molecules provide scientists with different information, which will be relevant in different contexts.
(a) Give the molecular formula of glucose [1]

(b) Give the molecular formula of fructose [1]

(c) Show the carbon skeletons of each of the open ring structures of each of the above molecules. [2]



Glucose



Fructose

(d) By reference to this example describe one piece of additional information that can be obtained by use of a carbon skeleton. [1]

(e) Describe the structural difference between starch and cellulose. [1]

(f) What further information is obtained by use of a three dimensional structure that would not be obtained if a carbon skeleton were used. [1]

8. At a given temperature, what does the Maxwell-Boltzmann speed distribution curve tell us? [2]

9. Ammonia is an essential compound in the Haber process which is used to synthesise ammonium nitrate (NH_4NO_3). Ammonium nitrate is used in the fertiliser and explosive industry. Large, scale-up production of ammonium nitrate involves the use of ammonia and therefore chemical engineers need to know the effect on the system for safety. If a given sample of 3.50 moles of ammonia gas is isolated (which occupies 5.20L at 47°C) calculate the pressure of the gas (in atm.). [2]

10. The gas pressure in an aerosol can is 2.0 atm at 25^{o}C. Assuming that the gas inside obeys the ideal-gas equation, what would the pressure be if the can was heated to 500^{o}C? [2]

11. A sample of CO_2 gas is initially at standard pressure and temperature (101325 pa and 298 K respectively). It is then compressed to a smaller volume at constant temperature. What effect does this change have on:
    (a) The average kinetic energy of CO_2 molecules.

    (b) The average speed of CO_2 molecules.

    (c) The total number of collisions of CO_2 molecules with the container walls in a unit time.

    (d) The number of collisions of CO_2 molecules with a unit area of the container wall per unit time?

    [4]

12. Give the type of motion and state how many degrees of freedom, are present in:
    (a) Xenon [1]
    (b) Oxygen [1]

[Total Marks 39]

Core Learning Exercise 04: Intermolecular Forces

Types of solid structure;

1. Indicate the type of crystal (molecular, metallic, covalent-network, or ionic) each of the following would form upon solidification:
   (a) $CaCO_3$
   (b) Pt
   (c) ZrO_2 (melting point, 2677^oC)
   (d) Kr
   (e) benzene
   (f) I_2. [3]

2. Which type (or types) of crystalline solid is characterised by each of the following:
   (a) high mobility of electrons throughout the solid,
   (b) softness, relatively low melting point,
   (c) high melting point and poor electrical conductivity,
   (d) network of covalent bonds,
   (e) charged particles throughout the solid.
   [5]

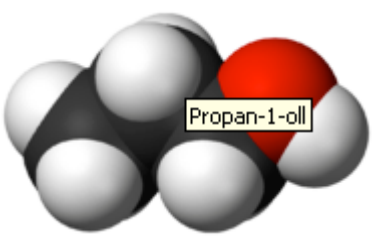
Intermolecular Forces

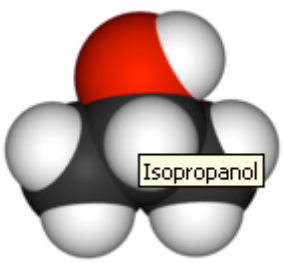
3. What type(s) of intermolecular force is (are) common to:
   (a) Xe and methanol (CH_3OH)
   (b) CH_3OH and acetonitrile (CH_3CN)
   (c) NH_3 and HF?
   [3]

4. Which member of the following pairs has the stronger intermolecular dispersion forces:
   (a) Br_2 or O_2
   (b) CH_3CH_2SH or $CH_3CH_2CH_2SH$ [3]

5. What type of intermolecular force accounts for the following differences:
   (a) CH_3OH boils at 65^oC, CH_3SH boils at 6^oC.
   (b) Xe is liquid at atmospheric pressure and 120K, whereas Ar is a gas.
   [2]

6. Propyl alcohol ($CH_3CH_2CH_2OH$) and isopropyl alcohol ($(CH_3)_2CHOH$), whose space-filling models are shown, have the boiling points of 97.2^oC and 82.5^oC respectively. Explain why the boiling point of Propyl alcohol is higher, even though both have the same molecular formula. [1]





Solutions

7. A chemist starts with 50.0 mL of a 0.40 M NaCl solution and dilutes it to 1000 mL. What is the concentration of NaCl in the new solution? [2]

8. A chemist wants to make 500. ml of 0.050 M HCl by diluting a 6.0 M HCl solution. How much of that solution should be used? [2]

9. What is the molarity of a solution made by dissolving 2.5 g of NaCl in enough water to make 125 ml of solution? [3]

10. (a) Explain what is meant by an electrolyte, giving an example of an electrolyte solution. [2]

    (b) Explain the difference between a strong and weak electrolyte. [2]

11. In the first step of the Ostwald process for the synthesis of nitric acid, ammonia is oxidised to nitric oxide by the following reaction:

$$4NH_3(g) + 5O_2(g) \longleftrightarrow 4NO(g) + 6H_2O(g) \qquad \Delta H° = -905.6KJ$$

    Chemists working at the plant need to know what would happen to the equilibrium mixture if the following occurred:
    (a) If the water is removed?
    (b) If the pressure in the reaction vessel decreases?
    (c) If the temperature in the reaction vessel decreases?
    (d) What rule describes the effects of these activities to an equilibrium reaction? [4]

12. When PCl_5 is heated in a sealed container and maintained at a container temperature, an equilibrium is established. At 500K, the following equilibrium concentrations were determined.

Substance	**Equilibrium**
PCl_5	0.065
PCl_3	0.125
Cl_2	0.125

    (a) Write an expression for K_c for the reaction.
    (b) Calculate a value for K_c. [2]

Acids and bases;

13. Explain what is meant by a 'strong acid'. Give 2 examples. [2]

14. A horticulturist working at the University of Leicester would like to know the pH of rainwater during the winter period to determine which flowers will grow best. The H^+ ion concentration of the rainwater was found to be 2.34×10^{-5}M. Using this data, calculate the pH for the horticulturist. [2]

15. A wine cognisor would like to know how much of the ethanol in a bottle of table wine has been oxidised to ethanoic acid after opening. It was found that the concentration of H^+ ions in the bottle was 3.2×10^{-4} M right after the cork was removed. Only half of the bottle was consumed. The other half, after it had been standing uncorked for a month, was found to have hydrogen ion concentration equal to 1.0×10^{-3} M. Calculate the pH of the wine on these two occasions.

16. The pH of household cleaning agents is important in its effectiveness. A common branded cleaner was analysed to determine the pH in order to maximise efficiency. The scientists found that the concentration of hydroxide ions (OH^-) in the cleaning solution was 4.47×10^{-4} M. Calculate the pH of this cleaner. [3]

17. Just as body temperature is maintained at 98.6°F, our blood is ideally maintained at 7.365 pH. Blood pH is a reliable method for estimating what's happening in the body's tissues. A doctor at the royal infirmary hospital in Leicester has sent a sample of a patient's blood to clinical scientists to determine the patient's blood pH. The doctor would like to know the pH to determine whether the patient suffers from metabolic acidosis (pH under 7.35). The HO^- ion concentration of the blood sample was found to be 2.5×10^{-7} M. What is the pH of the blood and does this patient suffer from metabolic acidosis? [3]

[Total marks 48]

Deliverable 01: Report

TV Remakes Unlimited intend to publish a companion website as the remake of the *A for Andromeda* series is aired. A section of this site will be devoted to the promotional hieroglyphic "message"; one page will be devoted to each hieroglyph and will be released each time a new episode is aired.

It is your task to compile the scientific information that will be presented on each webpage. The web development team hope that this site will become a useful resource for the fans of the series as well as people who are generally surfing the web. They have asked you to provide approximately 2000 words per hieroglyph, plus 500 words explaining the order of the hieroglyphs; the material should be presented at the same level as an undergraduate text book.

You will NOT be expected to design the site or webpages.

Meta tags

Author: Woodward, J.; Davies, D.; Ellis, A.; Evans, C.; Harrison, T.; Raine, D.; Ryder, K.; Williams,

Owner: University of Leicester

Title: Science of the Invisible Student Document

Classification: PA1012 / Science of the Invisible

Keywords: Atoms; Biology; Cells; Chemistry; Molecules; Problem-Based Learning; Physics; sfsoer; ukoer

Description: In *Science of the Invisible* you will explore the structure of microscopic objects from cells to molecules to atoms. At the smallest scale the world is governed by quantum mechanics which controls the properties of atoms and their binding to form molecules. You will also learn about the states of matter, gases liquids and solids, and how their properties arise from the properties of their constituents.

Language: English

File Size: 7.4MB

File Format: PDF

Version: 1.0

Additional Information

This module pack is the open student version of the teaching material. An expanded module pack for facilitators and additional information can be obtained by contacting the Centre for Interdisciplinary Science at the University of Leicester. http://www.le.ac.uk/iscience

This pack is the Version 1.0 release of the module.