Pittwater House

Year 11 Chemistry

Properties and Structure of Matter

Module 1

Student Name:

Year 11 Chemistry

Module 1

Properties and Structure of Matter

Contents

Introduction

The focus of the module is to assist you to analyse trends and patterns in relation to the properties of pure substances and use these to predict the properties of other pure substances. This knowledge is used to determine the ways in which substances can be separated from each other and those that allow them to remain together.

Matter can be either pure substances with distinct measurable properties (eg melting and boiling points, reactivity, strength, density) or mixtures with properties that are dependent on the identity and relative amounts of the substances that make up the mixture. The analysis of these properties has led to the expansion of the periodic table of elements and the advancement of atomic theory. This understanding has allowed for the development of complex models that have been subject to extensive peer review, and has contributed to advances in many disciplines over time.

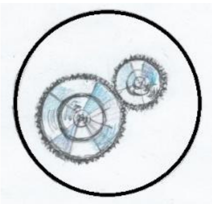
You will use knowledge obtained from the study of the periodic table to examine trends and patterns that exist between chemical elements and atoms in order to discover that fundamental particles, and their role in the structure of an atom, give all chemicals their properties.

There are four main areas of content:

1. Properties of Matter
2. Atomic Structure and Atomic Mass
3. Periodicity
4. Bonding

Through these areas of content, you will have the opportunity to explore the following questions:

1) How do the properties of substances help us to classify and separate them?
2) Why are atoms of elements different from one another?
3) Are there patterns in the properties of elements?
4) What binds atoms together in elements and compounds?



Inquiry question 1

- How do the properties of substances help us to classify and separate them?

Concept Map

https://padlet.com/col1904/11Chem_1_IQ_1

Homogeneous and heterogeneous mixtures

I can explore homogeneous mixtures and heterogeneous mixtures through practical investigations using separation techniques based on physical properties.

Watch video - PSM#1 Mixtures video

Properties and Structures of Matter

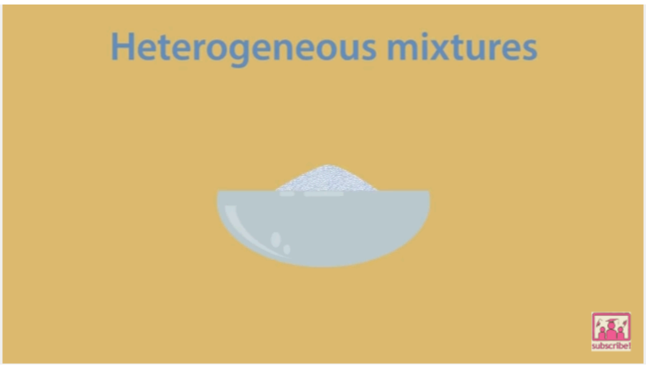
PSM#1 Mixtures

How do we classify matter?

Name the four types of mixtures.

Video: How to separate solution, mixtures and emulsions.

https://www.youtube.com/watch?v=XC1RxloV0Mo



Watch video - PSM#2 Separation Techniques

Properties and Structures of Matter

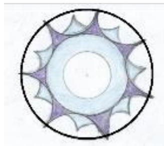
PSM#2 Separation Techniques

Complete the table to identify different methods of separation and the physical properties upon which they are based. The first one has been done for you.

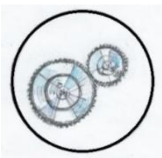
Separation Method	Physical properties	Example
Distillation	Differences in boiling points of miscible substances	Alcohol (ethanol) and water in solution

Problem

How could we separate the components of ONE of the following mixtures:



- iron filings, sand, salt, ethanol and water
- iron filings, calcium carbonate and potassium nitrate
- milk



Select an appropriate sequence of steps which you could use to separate the mixture identified above into its component substances. Justify each step. Carry out the experiment and record your results. (*PI Outcome, PI Content Statement 2*)

Additional Scaffold: Study ladder

https://www.studyladder.com.au/games/activity/separating-mixtures-29427

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

Physical or chemical changes in starch?

Examine some starch grains, eg. rice suspended in water, using a light microscope. Add some iodine to the suspension and record your results.

Heat the starch grains and during the boiling process, withdraw a sample of water and test the starch solution once more with iodine. “When starches are heated, the long polymer chain is broken into shorter lengths, called dextrins, which react differently with a solution of iodine” (Selinger, 2002, p. 77).

Properties and Structures of Matter Review Set 1

1. Explain the difference between a homogeneous mixture and a heterogeneous mixture, using an example of each (4 marks).

…………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

2. Compare and contrast a suspension, an emulsion and a colloid. (4 marks)

…………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

3. Suggest an appropriate separation technique for each of the following mixtures: (7 marks)
   a) Two solids with different sized particles …………………………………………..
   b) An insoluble solid in a liquid …………………………………………..
   c) A soluble solid in a liquid ..……………………………………………
   d) Two immiscible liquids …..…………………………………………
   e) Two miscible liquids ..……………………………………………
   f) Two gases which differ in molecular mass …..………………………………………
   g) The components in human blood …………………………………………….

4.

Gravimetric analysis

I can explore homogeneous mixtures and heterogeneous mixtures through practical investigations calculating percentage composition by weight of component elements and/or compounds.

Watch video - PSM#3 Gravimetric Analysis

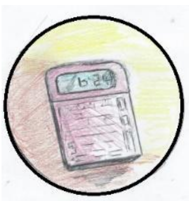
Properties and Structures of Matter

PSM#3 Gravimetric Analysis

To separate the parts of a mixture is one thing, but very often in industry or science it is important to measure the quantities or percentages of each fraction of the mixture.

Examples of where this might be important:

- o
- o
- o



Problem

Which is the saltiest beach on the northern beaches? How could we investigate this problem?

Properties and Structures of Matter Review Set 2

1. BHP has discovered a new deposit around Broken Hill believed to contain silver. They decide to carry out some tests to find out whether there is enough silver in the area to make it worthwhile mining. How could gravimetric analysis be helpful to BHP? In what other situations might gravimetric analysis supply useful data for chemists? (4 marks)

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

2. A dry mixture of soluble potassium sulfate and insoluble manganese dioxide was analysed gravimetrically as follows:

A weighed sample was thoroughly stirred into pure water, then filtered through a pre-weighed filter paper. The collected residue was oven dried and weighed.

Meanwhile, the filtrate was boiled in a preweighed evaporating basin until a dry solid formed, then weighed.

Results:

Mass of mixture sample = 4.96g

Mass of filter paper = 0.16g

Mass or paper + dried residue = 3.04g

Mass of evap.basin = 28.62g

Mass of basin + dry solid = 30.70g

a) Name the substance collected in the filter paper. (1 mark)

……………………………………………………………………………………………

b) Calculate the mass of this substance collected. (2 marks)

……………………………………………………………………………………………

……………………………………………………………………………………………

c) Calculate the % of this substance in the mixture. (2 marks)

……………………………………………………………………………………………

……………………………………………………………………………………………

d) Name the substance collected in the evaporating basin. (1 mark)

……………………………………………………………………………………………

e) Calculate the mass of this substance collected. (2 marks)

……………………………………………………………………………………………

……………………………………………………………………………………………

f) Calculate the % of this substance in the mixture. (2 marks)

……………………………………………………………………………………………

……………………………………………………………………………………………

g) What evidence is there that this analysis may be quite accurate? (2 marks)

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

h) Describe one technique, not mentioned in the outline above, which might have been done by the experimenter to help ensure accuracy. (Keep It Simple Science, 2007, p. 8) (2 marks)

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………………

3. What constitutes a 'fair' test in Science? (2 marks)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Nomenclature of inorganic substances

I can investigate the nomenclature of inorganic substances using International Union of Pure and Applied Chemistry (IUPAC) naming conventions.

Watch video - PSM#4 Inorganic Nomenclature

Properties and Structures of Matter

PSM#4 Inorganic Nomenclature

All chemists around the world need to be in communication with one another, especially as new elements are discovered. To improve communication and collaboration between chemists, the International Union of Pure and Applied Chemistry (IUPAC) produces sets of rules for naming chemical compounds which ensures their consistency. In their own words (International Union of Pure and Applied Chemistry, 2017):

> *"As one of its major activities, IUPAC develops Recommendations to establish unambiguous, uniform, and consistent nomenclature and terminology for specific scientific fields, usually presented as: glossaries of terms for specific chemical disciplines; definitions of terms relating to a group of properties; nomenclature of chemical compounds and their classes; terminology, symbols, and units in a specific field; classifications and uses of terms in a specific field; and conventions and standards of practice for presenting data in a specific field"*

It is important to begin the process of familiarising yourself with these rules. The following examples have been based on the 'Nomenclature for Inorganic Compounds' published by the University of Sydney (School of Chemistry, University of Sydney, 2014). You can follow the tutorial if you need a refresher.

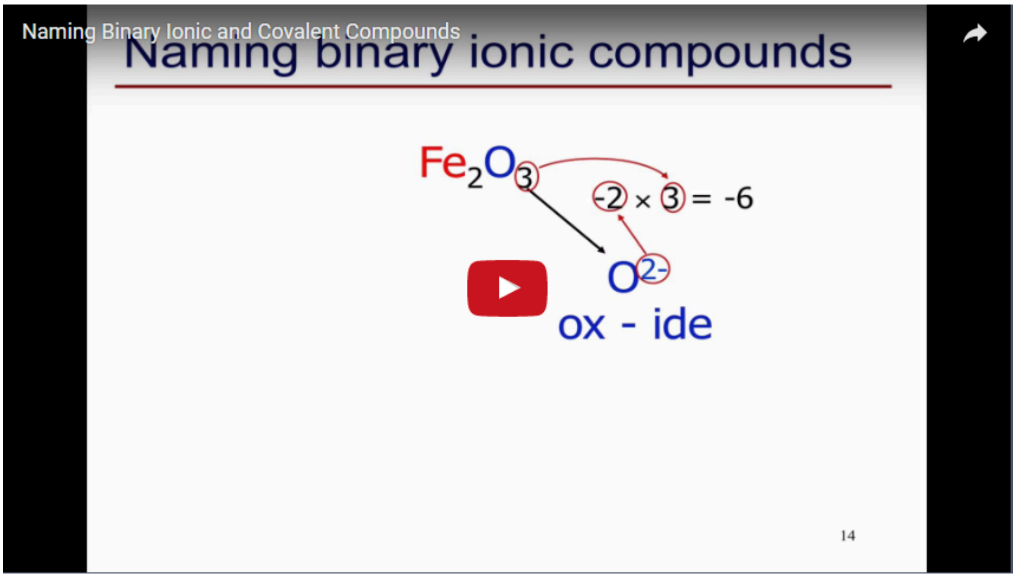


Figure 1: https://scilearn.sydney.edu.au/firstyear/videos/tutorials.cfm?video=ichem_inorganic_nomenclature

IUPAC have a presence on the internet and continue to update their site to ensure only the most up-to-date information is available. Here is a link to the most recent version of the Periodic Table: https://iupac.org/what-we-do/periodic-table-of-elements/

If all else fails, here are a few tips to help you naming inorganic (non-carbon based) compounds.

- Always name the metal first. It keeps its whole name, eg magnesium, sodium, copper, etc.
- If there is 1 non-metal, its ending is changed to 'ide'. So we have chlorine/chloride, oxygen/oxide, bromine/bromide.
- If the are 2 non-metals with a metal, one of which is oxygen, the other non-metal gets an 'ate' ending, eg nitrogen + oxygen = nitrate, carbon + oxygen = carbonate and so on

There are always exceptions to rules in Chemistry. It's one of the frustrations of Chemistry. So the 3rd rule sometimes gets varied to 'ite' and for the special case of hydrogen and oxygen to 'hydroxide'. Accept it now, worry later. ☺

Properties and Structures of Matter Review Set 3

1. Write the name of each radical shown below and indicate what charge it would have. The first one has been done for you.

Radical (polyatomic ion)	IUPAC Name	Charge
SO_3^{2-}	Sulfite ion	-2
SO_4^{2-}		
SO_3^{-}		
NO_3^{2-}		
CO_3^{2-}		
PO_4^{3-}		
NH_4^{+}		

2. Complete the table below to show the correct IUPAC name for each of the following inorganic substances. https://quizlet.com/_48cbtt (14 marks)

Name of Substance	Molecular Formula
	$CuSO_4$
	CO_2
	Fe_2O_3
	Na_2S
	K_3N
	$Mg(NO_3)_2$
	N_2O_4
	$CaCO_3$
	$Sr_3(PO_4)_2$

	MgO
	FeF_2
	Na_2CO_3
	$Cu(OH)_2$
	$NiSO_3$

Classifying elements based on physical properties

I can classify the elements based on their properties and position in the periodic table through their physical properties.

Watch video - PSM#5 Classifying elements based on their physical properties

Properties and Structures of Matter

PSM#5 Classifying elements based on physical properties

All chemical substances are either pure or impure. Impure substances, mixtures, have varying proportions of components and hence their properties can change.

Pure substances include elements and compounds. They contain only one type of atom (elements), or different atoms in a fixed ratio (compounds). This means they have predictable, and often measurable, physical and chemical properties.

There are around 90 naturally occurring elements (and a few more we’ve made in laboratories). Some of these elements occur naturally in either solid, liquid or gaseous state on earth. Most of the elements do not occur naturally. There is a simple rule to help us remember whether we are likely to find an element in an uncombined state.

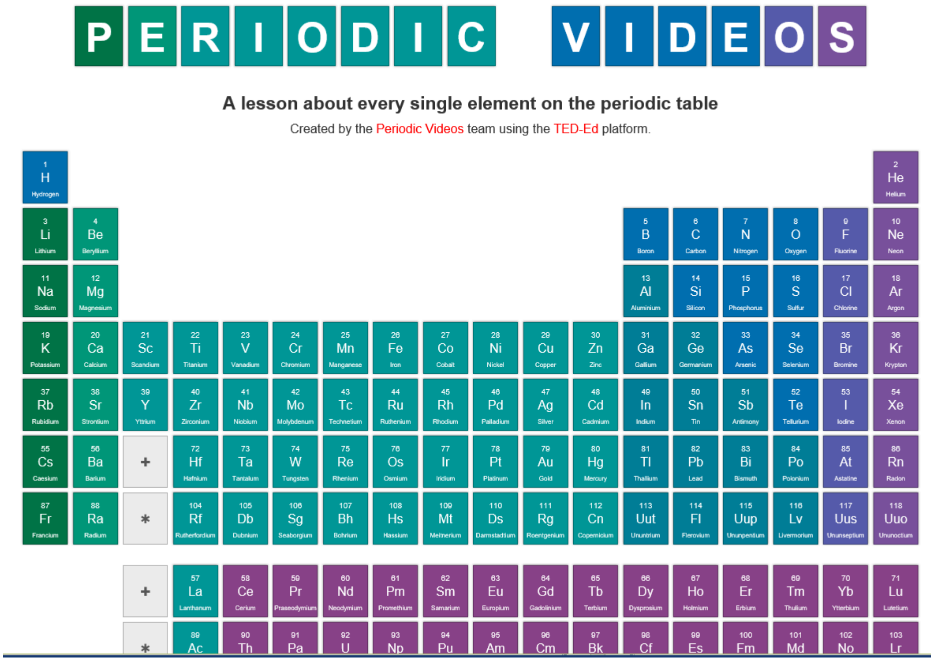
The (more/less) reactive an element is, the (less/more) likely it is to be found as an uncombined element.

Carry out an experiment to confirm this observation and identify the physical property which accounts for these observations. (Arbor Scientific, 2016)

Figure : Density differences

https://www.arborsci.com/cool/exploring-matter-chemistry-demonstrations/

The Periodic Table groups elements together based on similarities between their physical and chemical properties. We can investigate the properties and uses of different elements using the following interactive TED Ed link: http://ed.ted.com/periodic-videos



Properties and Structures of Matter Review Set 4

1. One way of making it easier to work with substances is to classify elements into one of three categories based on their physical properties. Complete the table on the following page: (24 marks)

Physical Property	Metals	Semi-metals	Non-metals
Melting Point			
Boiling Point			
Hardness			
Conductivity			
Lustre			

Malleable			
Ductile			
Density			

2. Rubidium (Rb) is located in the left column, and Neon (Ne) in the right-hand column of the Periodic Table.

   For each of the elements named predict its properties, including: (8 marks)

   i) general appearance and state at SLC,

   ii) electrical conductivity and

   iii) malleability and ductility, in the solid state.

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

Classifying elements based on chemical properties

I can classify the elements based on their properties and position in the periodic table through their chemical properties.

Watch video - PSM#6 Classifying elements based on chemical properties

Properties and Structures of Matter

PSM#6 Classifying elements based on chemical properties

All elements listed in the Periodic Table have been grouped on the basis of their physical and chemical properties. The elements in the same group exhibit a similar and predictable trend of properties.

One good example is the alkali metals in Group 1.

What are the members of this group and how can we describe the trends in their reactivity?

Period 2 Alkali metal:

Period 3 Alkali metal:

Period 4 Alkali metal:

Period 5 Alkali metal:

Period 6 Alkali metal:

Period 7 Alkali metal:

Trends in chemical activity within the group I elements.

ANNENBERG LEARNER

Properties and Structures of Matter Review Set 5

1. Gold is commonly found (I wish) in its elemental state. How does this relate to the reactivity of gold? (2 marks)

   ………………………………………………………..………………

   ……………………………………………………………………………..

   ………………………………………………………………………………………………

2. Sodium is very rarely found in its elemental state. How does this relate to the reactivity of sodium? (2 marks)

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

3. Colour the regions of the periodic table below as indicated. Describe the chemical reactivity for each group: (5 marks)

   - Alkali metals – red
   - Alkaline Earth metals – orange
   - Transition metals – yellow
   - Halogens – blue
   - Nobel gases - violet

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium						

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

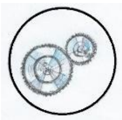
Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Elements with atomic numbers 113 and above have been reported but not fully authenticated.
Standard atomic weights are abridged to four significant figures.
Elements with no reported values in the table have no stable nuclides.
The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of data. Some data may ha ve been modified.

Inquiry question 2

- Why are atoms of elements different from one another?



Concept Map

https://padlet.com/col1904/11Chem_1_IQ_2

Atomic structure

I can investigate the basic structure of stable and unstable isotopes by examining the distribution of electrons, protons and neutrons in the atom.

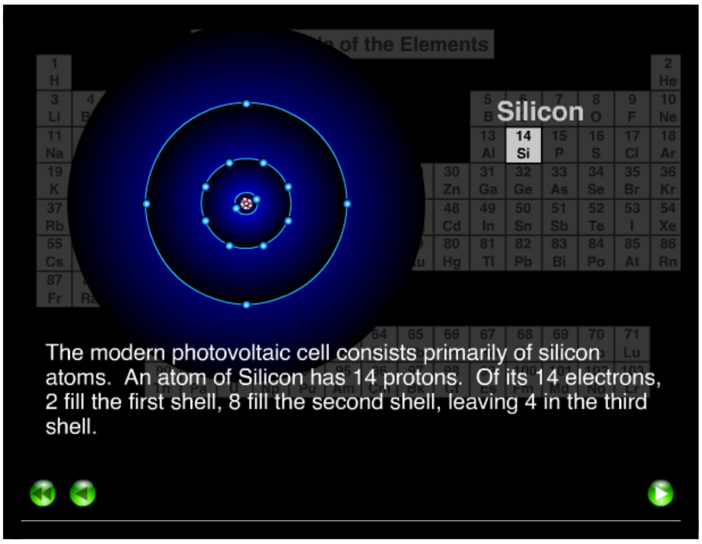
Watch video - PSM#7 Atomic structure

Properties and Structures of Matter

PSM#7 Atomic Structure

What is an atom?

http://science.sbcc.edu/physics/solar/sciencesegment/bohratom.swf



An atom has a **positively** charged nucleus which is surrounded by **negatively** charged electrons. The total positive and negative charge is equal so the atom as a whole is electrically **neutral**.

How do we define the atomic mass of an element?

Atomic number = number of protons + number of neutrons

NOTE: the electrons have almost no mass: 1/1800 that of a proton, so we do not consider them in a calculation of the mass.

What are isotopes and what makes some unstable?

Properties and Structures of Matter Review Set 6

1. Complete the following: (25 marks)

The atom consists of a nucleus containing positively charged _

_ _ _ _ _ _ and _ _ _ _ _ _ _ _ _ , which do not have a charge.

Around the nucleus are orbiting _ _ _ _ _ _ _ _ _ _ . These have a _ _ _ _ _ _ _ _ _ charge.

The electrons do not just roam about anywhere but appear to be confined to particular regions around the atom called _ _ _ _ _ _ _ _ _ _ _ _ . In order to move away from the nucleus from one level to a higher (_ _ _ _ _ _ _ _ state), they need to _ _ _ _ energy. When they return back to their original level (_ _ _ _ _ _ _ state) closer to the nucleus, they _ _ _ _ _ _ _ _ energy.

Almost all of the mass in an atom is contained within the _ _ _ _ _ _ _ _ . The electrons have very little mass (relative to _ _ _ _ _ _ _ _ and _ _ _ _ _ _ _ _ _).

The number of _ _ _ _ _ _ _ _ define the atom, ie it is unique for every atom. We call the number of protons, the _ _ _ _ _ _ _ number. Hydrogen has an atomic number of _ . This means that there is _ proton in its nucleus.

a) How many protons has carbon? ………..

b) What is the name of the element with 12 protons? ……………………………….

Since all of the mass of the atom is in the _ _ _ _ _ _ _ _, we can work out the mass number of an atom by adding the number of protons and neutrons together. Carbon has _ protons and _ neutrons in its nucleus. Hence, its mass number is _ _ .

c) What element has a mass number of 1? …………..

d) How many neutrons are in a typical sodium atom? ………………….

2. What is an isotope? (1 mark)

………………………………………………………………………………………………

………………………………………………………………………………………………

3. Which part(s) of the Periodic Table contains only unstable isotopes? (2 marks)

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

4. Identify the atomic number, the mass number and the name of each element for the following atoms: (15 marks)

6 p	12 p	17 p	18 p	92 p
6 n	13 n	18 n	22 n	143 n

Atomic Number

	Mass Number
	Name of Element

Isotopes

I can investigate the basic structure of stable and unstable isotopes by examining their position in the periodic table.

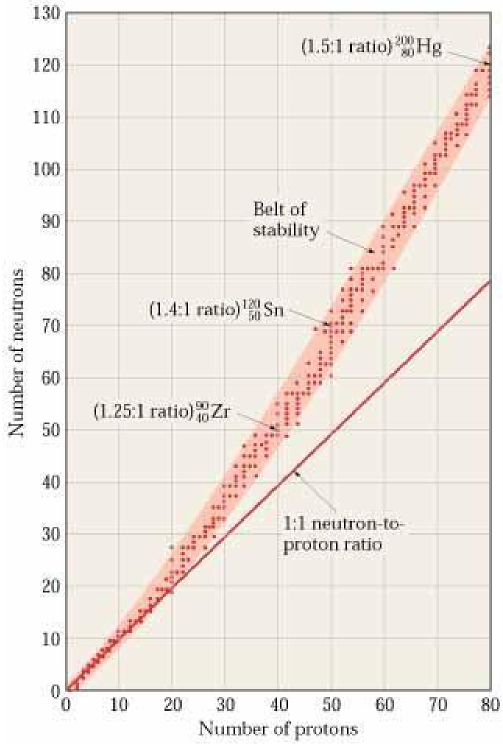
Watch video - PSM#8 Isotopes

Properties and Structures of Matter

PSM#8 Isotopes

Isotopes are atoms with the same number of protons, but with different numbers of neutrons.

As a result, isotopes have the same atomic number and hence are the same element, but they have different mass numbers. Because of this, isotopes are generally named by their mass numbers, such as rubidium-85 and rubidium-87.



A **stable isotope** is an isotope that has a stable nucleus and does not emit radiation.

A **radioisotope** is an isotope that has an unstable nucleus and emits radiation.

The nucleus of an isotope can be unstable for several reasons:

-

Properties and Structures of Matter Review Set 7

Worksheet

1. Locate the elements which have only unstable isotopic forms on the Periodic Table below. Shade them in grey. (2 marks)

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium						

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Elements with atomic numbers 113 and above have been reported but not fully authenticated.
Standard atomic weights are abridged to four significant figures.
Elements with no reported values in the table have no stable nuclides.
The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of data. Some data may ha ve been modified.

2. Describe the conditions under which a nucleus can be unstable. (3 marks)

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

3. Which of the following isotopes would you expect to be radioactive; U-235, U-238, U-239? Explain your answer. (2 marks)

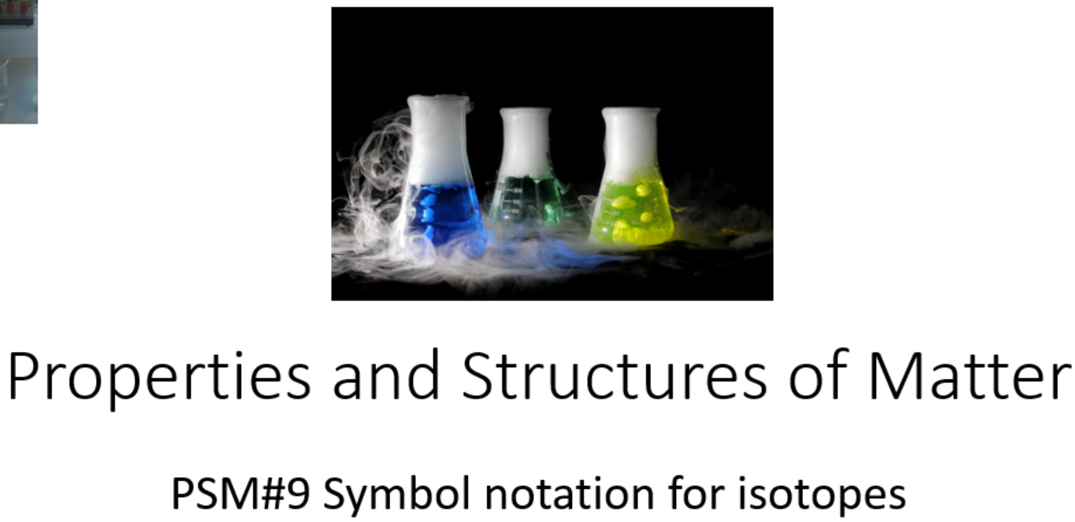
4. What is the significance of the transuranic elements? (2 marks)

5. Mark the position of the transuranic elements on the Periodic Table in question 1 using red shading over the grey. (2 marks)
6. Describe the method of formation of a transuranic element and its use. (4 marks)

Symbol Notation for atoms and isotopes

I can investigate the basic structure of stable and unstable isotopes by examining representation of the symbol, atomic number and mass number (nucleon number).

Watch video - PSM#9 Symbol notation for isotopes



Once we acknowledge the existence of both stable and unstable forms of an element, we need a method for symbolising the different isotopes.

We can represent isotopes using the symbols: $^{A}_{Z}\mathrm{M}$

where: M is the chemical symbol for the element, A is the mass number and Z is the atomic number.

Hence oxygen-16 could be represented as $^{16}_{8}\mathrm{O}$, while oxygen-18 would be $^{18}_{8}\mathrm{O}$

Mass number is often referred to as **nucleon** number. This is the sum total number of particles (protons and neutrons) in the nucleus. The electrons do not contribute significantly to the mass of the atom, hence they do not form part of the calculation of its mass.

Properties and Structures of Matter Review Set 8

1. Hydrogen exists in three isotopic forms; hydrogen-1, hydrogen-2 (deuterium) and hydrogen-3 (tritium). Use symbol notation to represent these three isotopes. (3 marks)

2. Use the periodic table to write down the symbol notation for the most likely stable isotope for each of the first 20 element. (20 marks)

3. Radioisotopes have been used in dating rocks and fossils. Research two different radioisotopes which are used by palaeontologists and identify the atomic notation, the decay product, the half-life and the types of rocks/fossils most commonly aged using each one. (8 marks)

Electron configuration

I can model the atom's discrete energy levels, including electronic configuration and spdf notation.

Watch video - PSM#10 Electron configuration

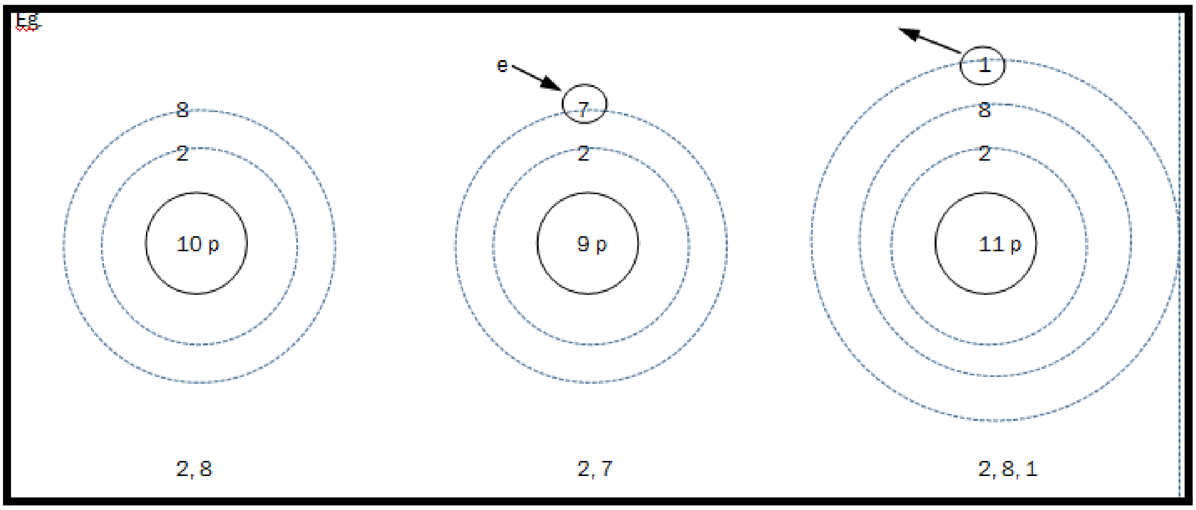
Properties and Structures of Matter

PSM#10 Electron configuration

The diagrams below represent the atoms of neon, fluorine and sodium respectively.

We can represent the electron configuration of each element as follows:

neon: 2.8 fluorine: 2.7 sodium: 2.8.1



Rules for the Bohr model:

1. Each shell contains a maximum number of electrons. This can be found using the formula $2n^2$, where n is the shell number, ie the first shell has a maximum of $2 \times 1^2 = 2$ electrons.
2. The lower energy levels fill before the higher levels (Aufbau Principle). #

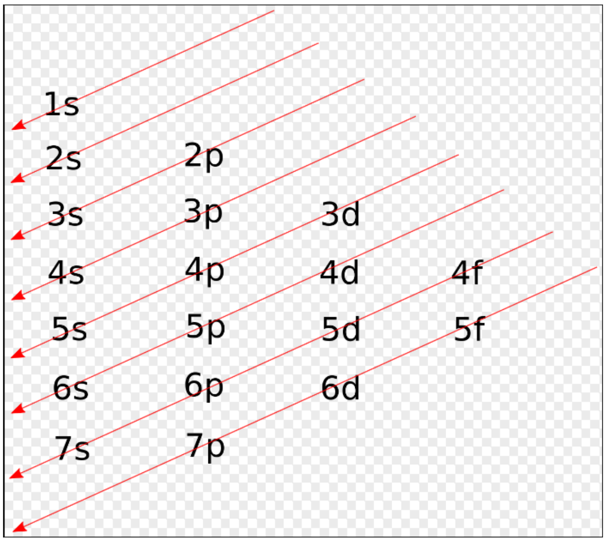
3. Electrons fill in a particular order.

One of the many frustrating things about the study of Chemistry is the exceptions to the rules. The second of these rules works up to element 18. After 18, we need a more precise model to help us explain what is happening.

spdf notation

Subshell electron numbers (maximum per subshell) are:

s = 2, p = 6, d = 10 and f = 14. Now we can examine how we remember the order in which they are filled. The diagram right may prove useful. How can we link this order to the organisation of elements in the Periodic Table?



So for the examples above, if we expand the electron configuration to include spdf notation, it becomes:

fluorine: $1s^2\ 2s^2\ 2p^5$ neon: $1s^2\ 2s^2\ 2p^6$ sodium: $1s^2\ 2s^2\ 2p^6\ 3s^1$

Properties and Structures of Matter Review Set 9

1. Complete the table by writing the electron configuration using subshell notation for the listed elements. The first one has been completed for you. (5 marks)

Element	Electron configuration
Copper	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9\ 4s^2$
Aluminium	
Calcium	
Iodine	
Uranium	
Rubidium	

Relative atomic mass

I can calculate the relative atomic mass from isotopic composition.

Watch video - PSM#11 Relative atomic mass

Properties and Structures of Matter

PSM#11 Relative Atomic Mass

The existence of multiple isotopes of a particular element can create issues when we are trying to work out the atomic mass.

To overcome this, we use the concept of **relative atomic mass**.

To calculate the relative atomic mass of a particular isotope, we need to take into account the relative proportions of each.

Eg. If 95% of hydrogen exists as H-1, 4.5% as H-2 and just 0.5% as H-3, what would be the relative atomic mass of hydrogen?

To answer this we use the following steps:

Contribution of H-1 to the mass:	0.95 x 1 = 0.95	+
Contribution of H-2 to the mass:	0.045 x 2 = 0.090	+
Contribution of H-3 to the mass:	0.005 x 3 = 0.015	=
Total relative atomic mass of hydrogen	1.055 amu	

Properties and Structures of Matter Review Set 10

1. Look at the relative atomic mass of hydrogen in the Periodic Table. How does it compare to the one calculated above? What does this tell you about the relative abundance of the three naturally-occurring isotopes of hydrogen? (3 marks)

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

2. Chlorine has a large number of isotopes with mass numbers ranging from 28 to 51. However the two most common, stable isotopes of chlorine are chlorine-35, which has a relative abundance of 75.78% and chlorine-37 which has a relative abundance of 24.22%. Use these two isotopes to calculate the relative atomic mass of chlorine. (3 marks)

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

3. Titanium is a metal which can be mined from certain beach sands and has some extremely useful properties. It has been used in the manufacture of light but strong structures ranging from dental implants to golf clubs and prostheses. There are a number of radioactive isotopes of titanium, however there are five stable forms. In a common sample of titanium, the relative abundance of each of these isotopes would be titanium-46 - 8.25%, titanium-47 7.44%, titanium-48, the most common isotope is 73.72%, titanium-49 is 5.41%, while titanium 50 is 5.18%. Use these abundances to calculate the relative atomic mass of titanium. (3 marks)

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

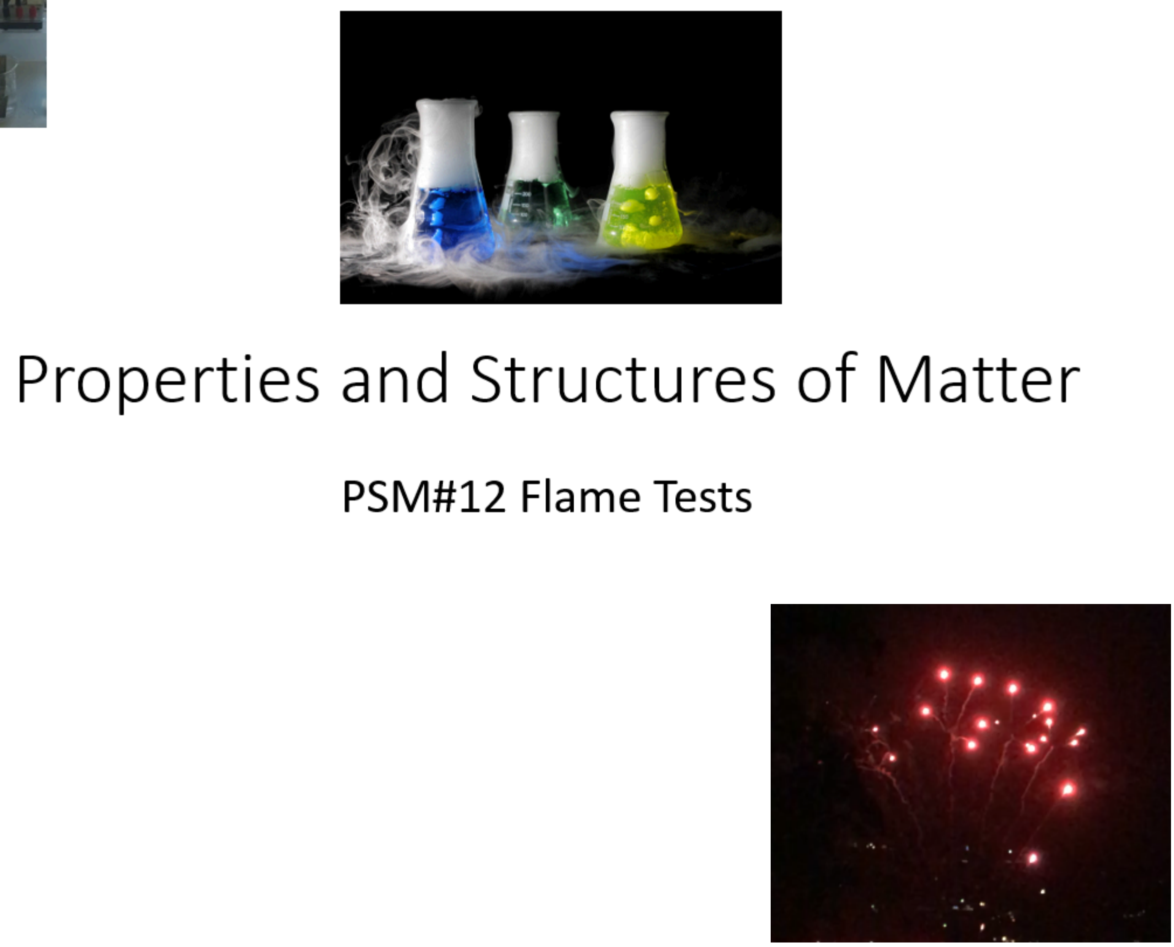
……………………………………………………………………………………………

……………………………………………………………………………………………

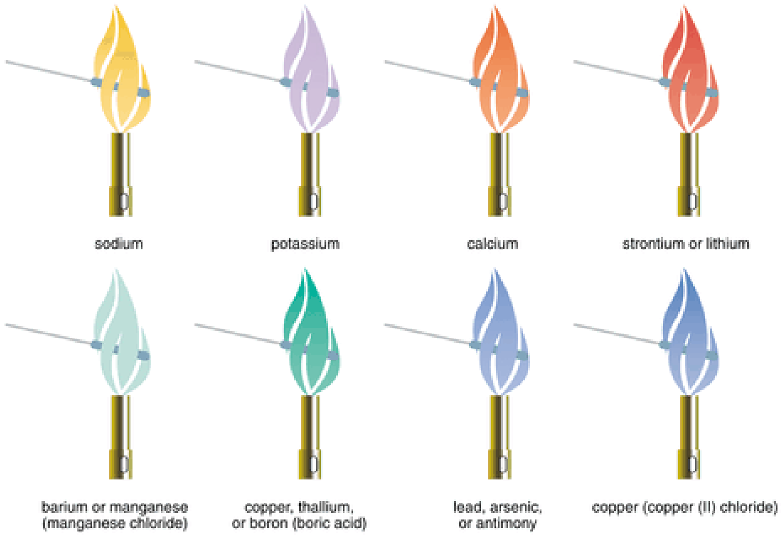
Flame tests

I can investigate energy levels in atoms and ions through collecting primary data from a flame test using different ionic solutions of metals.

Watch video - PSM#12 Flame Tests



A spectacular example of what happens when electrons get excited is fireworks. Make a note of the number of different colours you can see next time you are watching fireworks.



Properties and Structures of Matter Review Set 11

1. Complete the table below to show the dominant flame colour for each of the following metals. (10 marks)

Element	Flame Colour
Sodium	
Potassium	
Calcium	
Strontium	
Barium	
Copper	
Lithium	

2. Look at the spectroscopy chart for various elements shown below (from the following website: https://www.auburn.edu/academic/classes/scmh/1010/Flame_clip_image002.jpg).

a) Use this data to explain the colour of the sodium flame. (2 marks)

b) Explain why each element has more than one coloured line. (3 marks)

…………………………………………………...

…………………………………………………...

…………………………………………………...

…………………………………………………...

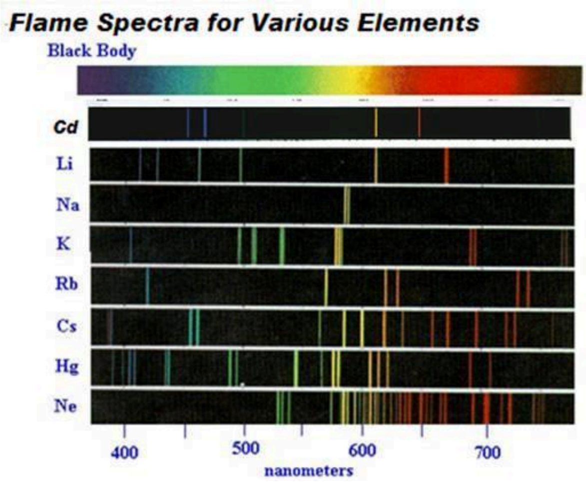
…………………………………………………...

…………………………………………………...

…………………………………………………...

…………………………………………………...

…………………………………………………...



………………………………………………...

………………………………………………...

………………………………………………...

Schrödinger model of the atom

I can investigate energy levels in atoms and ions through examining spectral evidence for the Bohr model and introducing to the Schrödinger model.

Watch video - PSM#13 Schrödinger model of the atom

Bohr's atomic model

Schrödinger's Model

While Bohr's model explained the properties of the hydrogen atom, it was less successful in explaining the behaviour of multi-electron atoms. A better explanation was provided by Schrödinger's "wave-particle" model.

He treated the electron as a wave-form and was able to devise mathematical equations to describe it in terms of probability functions.

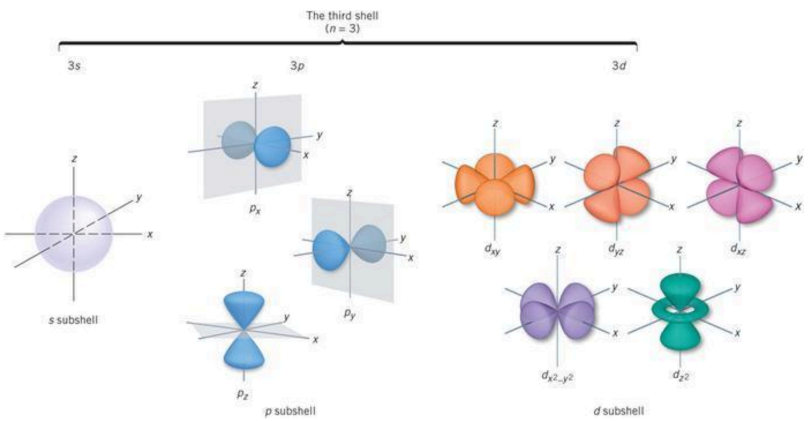
Evidence from the study of spectra and chemical bonds suggests that the electrons are in distinct sub-shells within each shell. In Bohr's theory, each shell is labelled with a number representing the principal quantum number, so in Schrodinger's wave equations, integral values are a fundamental component of solutions to the wave equations. We now recognise the following pattern of subshells:

* s	(spherical shape)	(sharp)	(classifications used
* p	(polar shape)	(principal)	by spectroscopists
* d		(diffuse)	in referring to
* f		(fundamental)	spectral lines.)

Shell	Number of sub-shells	Symbols for sub-shells
n = 1 (K)	1	1s
n = 2 (L)	2	2s, 2p
n = 3 (M)	3	3s, 3p, 3d
n = 4 (N)	4	4s, 4p, 4d, 4f
n = 5 (O)	5	5s, 5p, 5d, 5f, 5g

The symbols used to denote sub-shells includes a number referring to the shell and a letter referring to the shape of the orbital within the sub-shell. There is a limit of two electrons in each orbital (the limit is known as the Pauli exclusion principle). Each orbital has a particular shape. The s orbitals are spherical, p are dumbbell shaped (aligned along x, y and z axes). The shapes of the other orbitals are more complex and not a part of this course.

The 3s orbital occupies a larger space than the 2s (> 1s). The p orbitals overlap the s orbitals, but the electrons within the orbitals do not interact with one another.



In the hydrogen atom, the sub-shells have the same energies as the principal energy shell. However, in multi-electron atoms, the energy pattern is not as simple. There is some overlap between upper sub-shells and lower sub-shells.

Properties and Structures of Matter Review Set 12

1. What is the major difference between the Bohr model and the Schrödinger model of the atom? (1 mark)

   ……………………………………………………………………..

   ……………………………………………………………………..

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

2. What was the limitation in the Bohr model which led to the development of a different model of the atom? (2 marks)

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

3. Orbital configurations help us explain elements with variable valencies. Sulfur may have a valency of -2, +4 and +6. Explain how sulfur might be able to exist is all three forms. (3 marks)

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

Radiation and radioisotopes

I can investigate the properties of unstable isotopes using natural and human-made radioisotopes as examples, including types of radiation.

Watch video - PSM#14 Radiation and radioisotopes

Properties and Structures of Matter

PSM#14 Radiation and radioisotopes

The three different types of radiation all have the ability to ionise gases:

-
-
-

Radioactive particles are also energetic. They have the ability to penetrate both air and different materials. However like ionising ability, they also differ in terms of their penetration power.

-
-
-

Radioisotopes can be used to generate electricity. While this occurs in other parts of the world, there is currently a bipartisan agreement in Australia not to use our nuclear technologies for power generation. How does this ongoing decision impact on our sustainable use of resources?

Properties and Structures of Matter Review Set 13

1. What are the key differences between the three types of radiation? (3 marks)

   ………………………………………………………………………..

   ………………………………………………………………………..

   ………………………………………………………………………..

   …………………………………………………………………………………………………

   …………………………………………………………………………………………………

   …………………………………………………………………………………………………

2. What are the most important properties associated with radioactive isotopes and/or radioactive particles? Discuss the three type of radiation in relation to these two properties. (6 marks)

3. Construct a table to compare the methods of detection for the three types of radiation. (3 marks)

Nuclear reactions

I can investigate the properties of unstable isotopes using natural and human-made radioisotopes as examples, including types of balanced nuclear reactions.

Watch video - PSM#15 Nuclear reactions

Properties and Structures of Matter

PSM#15 Nuclear Reactions

A **Radioisotope** is an isotope that has an unstable nucleus and emits radiation.

The nucleus of an isotope can be unstable for several reasons:

- .

- .

- .

What conditions are likely to trigger gamma decay? Write a nuclear equation to represent this process. (Hint: use Tc-99m)

Properties and Structures of Matter Review Set 14

1. Which of the following lists contains ONLY unstable isotopes? (11, Q7)
   A) 207 82 Pb, 99 43 Tc, 12 7 N

   B) 214 82 Pb, 46 20 Ca, 99 43 Tc

   C) 238 92 U, 40 20 Ca, 12 7 N

   D) 238 92 U, 40 20 Ca, 99 43 Tc

2. Which of the following is an important factor in predicting the nuclear stability of an isotope? (09, Q1)
   (A) Atomic radius
   (B) Nuclear radius
   (C) The ratio of neutrons to protons
   (D) The ratio of electrons to protons
3. Which set contains only stable nuclei? (06, Q3)
   A) 2 1 H, 12 6 C, 238 92 U

   B) 16 8 O, 39 19 K, 12 6 C

   C) 65 30 Zn, 18 8 O, 24 12 Mg

   D) 14 6 C, 16 8 O, 1 1 H

4. Describe the conditions under which a nucleus is unstable. (02, Q19 a), 2 marks)

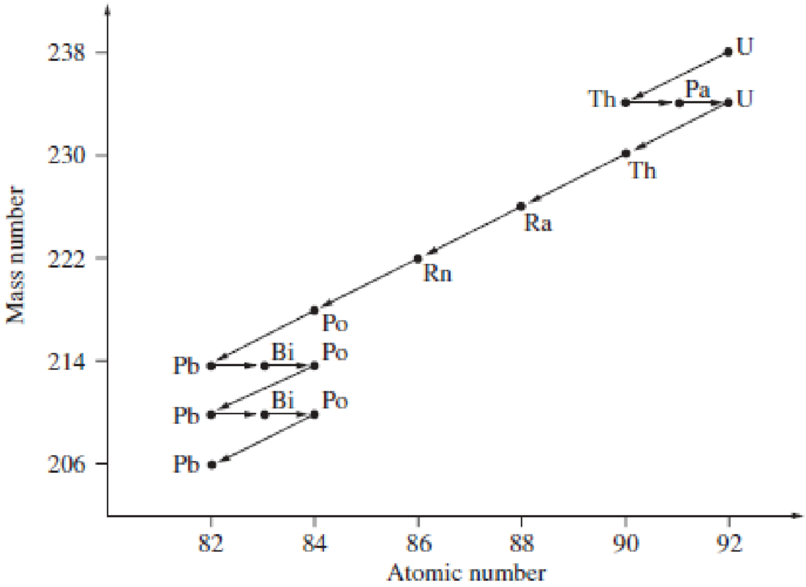
   ……………………………………………………………………………………………

   ……………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

5. The following is a flow diagram showing the sequence of products released during the decay of uranium. (02, Q19 b) 3 marks)



Use examples from the flow diagram to describe processes by which an unstable isotope undergoes radioactive decay.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Applications of radioisotopes

I can investigate the properties of unstable isotopes using natural and human-made radioisotopes as examples including applications of radioisotopes.

Watch video - PSM#16 Applications of Radioisotopes

Properties and Structures of Matter

PSM#16 Applications of Radioisotopes

Commercial radioisotopes are radioisotopes that are used in medicine, industry and/or scientific research.

Commercial radioisotopes are produced in two main ways

-
-

One common example of a commercial radioisotope is Am-241. This was widely used in smoke detectors. It has subsequently been replaced in many modern smoke detectors by a photoelectric device.

Case Study Report

1. Am-241 was produced through bombardment of Pu-239 with neutrons. Show how Pu-239 could be used to produce Am-241. (3 marks)

   …………………………………………………………………

   ………………………………………………………………………………………………………

2. The reason Am-241 was widely used is based on three properties; its half-life and the penetrating power and ionising ability of its decay particle. Use this information to write a balanced equation of the radioactive decay of Am-241. Identify the decay product and any other product(s). Explain how the three key properties of Am-241 are linked to its use. (6 marks)

3. There have been significant issues with radiation as a result of incidents at Chernobyl and Fukushima. Evaluate the efficacy of nuclear power as an energy generator for the 21st Century. (5 marks)

Inquiry question 3

- Are there patterns in the properties of elements?

Concept Map

Melting and Boiling Point Trends

I can demonstrate, explain and predict the relationships in the observable trends in the physical and chemical properties of elements in periods and groups in the periodic table, including state of matter at room temperature.

Watch video - PSM#17 Periodic Trends

Melting point

Element	Melting Point (°C)
Hydrogen	-259
Helium	-272
Lithium	180
Beryllium	1278
Boron	2300
Carbon	3550
Nitrogen	-210
Oxygen	-219
Fluorine	-220
Neon	-249
Sodium	98
Magnesium	650
Aluminium	660
Silicon	1410
Phosphorus	590
Sulfur	113
Chlorine	-101
Argon	-189
Potassium	63
Calcium	842

From the SI Chemical Data Book 6th Ed. (Aylward & Findlay, 2008)

Boiling point

Element	Boiling Point (ºC)
Hydrogen	
Helium	
Lithium	
Beryllium	
Boron	
Carbon	
Nitrogen	
Oxygen	
Fluorine	
Neon	
Sodium	
Magnesium	
Aluminium	
Silicon	
Phosphorus	
Sulfur	
Chlorine	
Argon	
Potassium	
Calcium	

Properties and Structures of Matter Review Set 15

1. Plot the melting points of the first 20 elements on a grid, using the values provided on the previous page. Prepare a brief report describing the trends you observe, taking into account both group and period trends. (10 marks)
2. Plot the boiling points of the first 20 elements on a grid. Prepare a brief report describing the trends you observe, taking into account both group and period trends.

(10 marks)

I can demonstrate, explain and predict the relationships in the observable trends in the physical and chemical properties of elements in periods and groups in the periodic table, including electronic configurations and atomic radii.

Electronic Configuration and Atomic Radius

Watch video - PSM#18 Trends in Electron configuration

Properties and Structures of Matter

PSM#18 Trends in electron configuration

Electron configuration

The arrangement of electrons around the nucleus of an atom is called the **electron configuration**. As discussed earlier, the electrons are in distinct sub-shells within each

shell. An examination of the electron configuration can help us identify patterns across a period and also down different groups. For example, have a look at the electron configuration for the Group I active metals.

Lithium: $1s^2\ 2s^1$

Sodium: $1s^2\ 2s^2\ 2p^6\ 3s^1$

Potassium: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 2p^6\ 4s^1$

Rubidium: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 5s^1$

Note the pattern for this group. The valence shell (or highest number) has just 1 electron in an s orbital. This is an important feature as it helps chemists understand how and why these metals are so reactive and tend to form ionic salts.

Atomic radius

Element	Atomic Radius (pm)
Hydrogen	
Helium	
Lithium	
Beryllium	
Boron	
Carbon	
Nitrogen	
Oxygen	
Fluorine	
Neon	
Sodium	
Magnesium	
Aluminium	
Silicon	
Phosphorus	
Sulfur	
Chlorine	
Argon	
Potassium	
Calcium	

Properties and Structures of Matter Review Set 16

Worksheet

1. Write the electron configurations, using subshell notation for the elements of Period 4, Group II and Group VIII (or XVIII). Prepare a brief report describing the trends you observe, taking into account either group or period trends. (10 marks)
2. Plot the atomic radius of the first 20 elements on a grid. Prepare a brief report

describing the trends you observe, taking into account both group and period trends. (10 marks)

I can demonstrate, explain and predict the relationships in the observable trends in the physical and chemical properties of elements in periods and groups in the periodic table, including first ionisation energy and electronegativity.

First ionisation energy and electronegativity

Ionisation Energy

Ionisation Energy refers to the amount of energy required to remove an electron from an atom or ion in its gaseous state.

First Ionisation Energy refers to the energy required to remove the first electron from a stable atom, turning it into an ion.

Element	1st Ionisation Energy (MJ/mol)
Hydrogen	
Helium	
Lithium	
Beryllium	
Boron	
Carbon	
Nitrogen	
Oxygen	
Fluorine	
Neon	
Sodium	
Magnesium	
Aluminium	
Silicon	
Phosphorus	
Sulfur	

Chlorine	
Argon	
Potassium	
Calcium	

Electronegativity

Electronegativity is a measure of the tendency of an atom of an element to attract electrons.

Element	Electronegativity (Pauling units)
Hydrogen	
Helium	
Lithium	
Beryllium	
Boron	
Carbon	
Nitrogen	
Oxygen	
Fluorine	
Neon	
Sodium	
Magnesium	
Aluminium	
Silicon	
Phosphorus	
Sulfur	
Chlorine	
Argon	
Potassium	
Calcium	

Properties and Structures of Matter Review Set 17

Worksheet

1. Contrast the term 'ionisation energy' with 'electronegativity'. Is it reasonable to think about one term as representing the reverse of the other term?

....

....

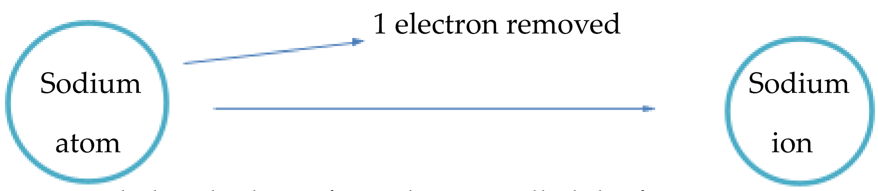
....

....

2. Complete the following:

   The reactivity of metals increases as their first ionisation energy _ _ _ _ _ _ _ _ _ _ .

   In other words, the lower the ionisation energy the _ _ _ _ _ _ it is to remove an electron and hence the _ _ _ _ active the metal is.



   The energy needed to do this is for sodium is called the first _ _ _ _ _ _ _ _ _ _ energy.

3. How is ionisation energy related to the activity of different metal species? Use an example to explain your response.

....

....

....

....

4. How is electronegativity related to the chemical activity of different elements? Use an example to explain your response.

....

....

....

....

5. Explain why the 2nd ionisation energy for an element is always higher than the 1st.

   ....

   ....

   ....

6. Plot the first ionisation energy of the first 20 elements on a grid. Prepare a brief report describing the trends you observe, taking into account both group and period trends. (10 marks)
7. Plot the electronegativity of the first 20 elements on a grid. Prepare a brief report

describing the trends you observe, taking into account both group and period trends. (10 marks)

I can demonstrate, explain and predict the relationships in the observable trends in the physical and chemical properties of elements in periods and groups in the periodic table, including reactivity with water.

Reactivity with water

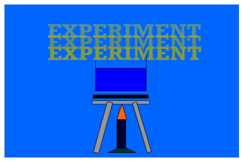
Watch video - PSM#19 Trends in chemical reactivity

The previous examples focussed on the observable trends in many of the physical properties of elements. How they behave with other elements can also provide information which can be interpreted on the basis of trends across a period or down a group. One such example is their reaction with water.

Element + water example: sodium + water

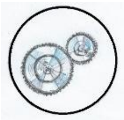
Observations:

Products of the reaction:



It is important to note the difference between a chemical reaction (chemical change) and the formation of a solution (physical change). If the substance neither dissolves nor reacts, it is more easily classified.

Properties and Structures of Matter Review Set 18



1. Using specific examples of both metals and non-metals, construct word equations and balanced formulae equations to represent the reactions between an element and water. (4 marks)

   ....

   ....

   ....

   ....

   ....

   ....

2. Prepare a brief report describing the trends in chemical reactivity with water, taking into account both group and period trends. (10 marks)

Other periodic trends

I can demonstrate, explain and predict the relationships in the observable trends in the physical and chemical properties of elements in periods and groups in the periodic table.

Watch video - PSM#20 Oxides and the Periodic Table

Properties and Structures of Matter

PSM#20 Oxides and the Periodic Table

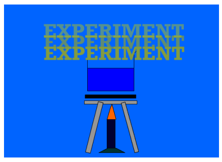
Reactions involving oxygen

Reaction of an element with water is one example of a chemical property which can be examined for elements in the same group or period. Two other chemical properties include reaction with oxygen and reaction with dilute acid.

Element + oxygen   example: magnesium + oxygen

Observations:

Products of the reaction:



Oxides of metals have different chemical properties to the oxides of non-metals. We can demonstrate the difference by dissolving the elemental oxide in some water and testing its pH using universal indicator.

Reactions involving dilute acids

Another chemical property which we can investigate involves the reaction of an element with dilute acid.

Element + dilute acid   example: zinc + hydrochloric acid

Observations:

Products of the reaction:

Combing power (valency)

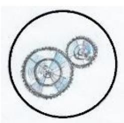
The combining power or valency is the same for each element in a group, however it increases by one as we go across a period. The first group (active metals) have a valency of +1, the second (alkaline earth metals) +2, then +3, ±4, -3, -2, -1 (halogens) and the noble gases have a valency of 0. (Skip the transition metals, they will be dealt with separately later).

Reactivity

For the metals, reactivity increases down the group and decreases across the period. However, after Group IV, reactivity decreases down the group and increases across the period up to the noble gases, which are inert). This means the two most reactive elements are Fr (bottom of Group 1) and F (top of Group VII).

Properties and Structures of Matter Review Set 19

1. Using specific examples of both metals and non-metals, construct word equations and balanced formulae equations to represent the reactions between an element and oxygen. (4 marks)



2. Using specific examples of both metals and non-metals, construct word equations and balanced formulae equations to represent the reactions between an elemental oxide and water. (4 marks)

....

....

....

3. Describe the regions of the Periodic Table in terms of the types of oxides formed in water. Include the terms; ‘acidic oxide’ and ‘basic oxide’ in your response. (3 marks)

....

....

....

....

....

....

Inquiry question 4

- What binds atoms together in elements and compounds?

Concept Map

Electronegativity and Chemical Bonds

I can investigate the role of electronegativity in determining the ionic or covalent nature of bonds between atoms.

Watch video - PSM#21 Electronegativity and chemical bonding

Electronegativity, the measure of the ability of an atom to attract an electron, is a key determinant in helping us identify the nature of the bond which may form between two atoms.

Ionic bonds

Covalent bonds

As electronegativity differences increase between neighbouring atoms in a compound, the percentage ionic character of the bond increases.

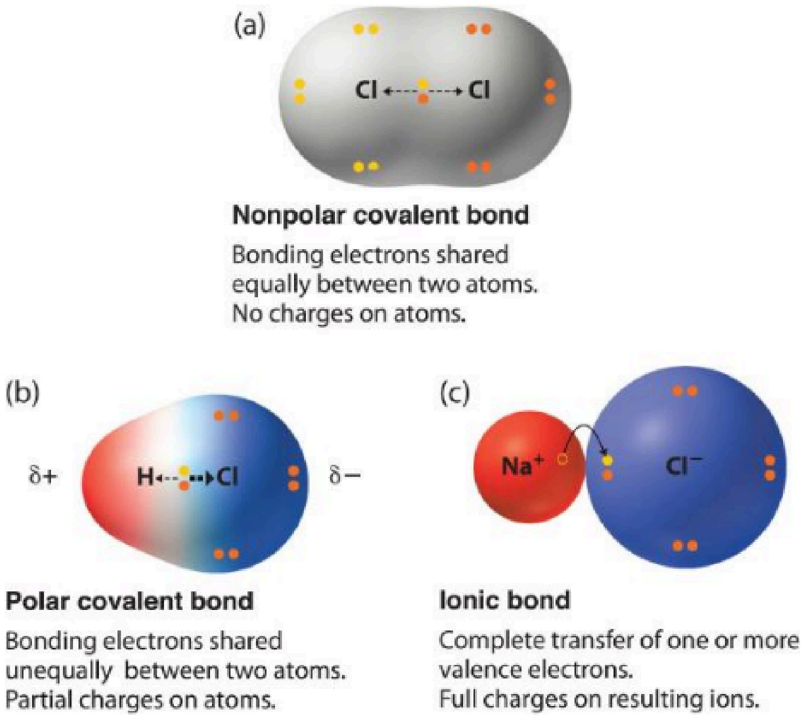


Figure 3: Nature of bonds between atoms
https://chem.libretexts.org/Textbook_Maps/General_Chemistry_Textbook_Maps/Map%3A_Chemistry%3A_The_Central_Science_(Brown_et_al.)/08._Basic_Concepts_of_Chemical_Bonding/8.4%3A_Bond_Polarity_and_Electronegativity

This can be demonstrated using the elements in period 3. Values obtained from (Aylward & Findlay, 2008, p. 126)

Bond	Electronegativity difference	Percentage ionic character (approx.)
Na – Cl	3.16 - 0.93 = 2.23	
Mg – Cl	3.16 - 1.31 = 1.85	
Al – Cl	3.16 - 1.61 = 1.55	
Si - Cl	3.16 - 1.90 = 1.26	
P – Cl	3.16 - 2.19 = 0.97	
S – Cl	3.16 - 2.58 = 0.58	
Cl – Cl	3.16 – 3.16 = 0	

Note: If the electronegativity differences > 1.5-1.7, then the bond is considered to be ionic. eg. Na – Cl, has an electronegativity difference of 2.1 and is considered to be ionic. The highest value for this difference is 3.3 (between Cs and F, making CsF the most ionic compound which may be formed).

Properties and Structures of Matter Review Set 20

1. How do we determine which type of bond is likely to form between two atoms? (2 marks)

2. Given the electronegativity values for the Period 2 elements, construct one ionic compound and one covalent compound. Justify your decisions and evaluate the degree of polarity of your covalent substance. (6 marks)

   Electronegativity values (Pauling Scale):
   Li – 0.98, Be – 1.57, B – 2.04, C - 2.55, N - 3.04, O - 3.44, F – 3.98 (Aylward & Findlay, 2008, p. 126)

Ionic and Covalent Compounds

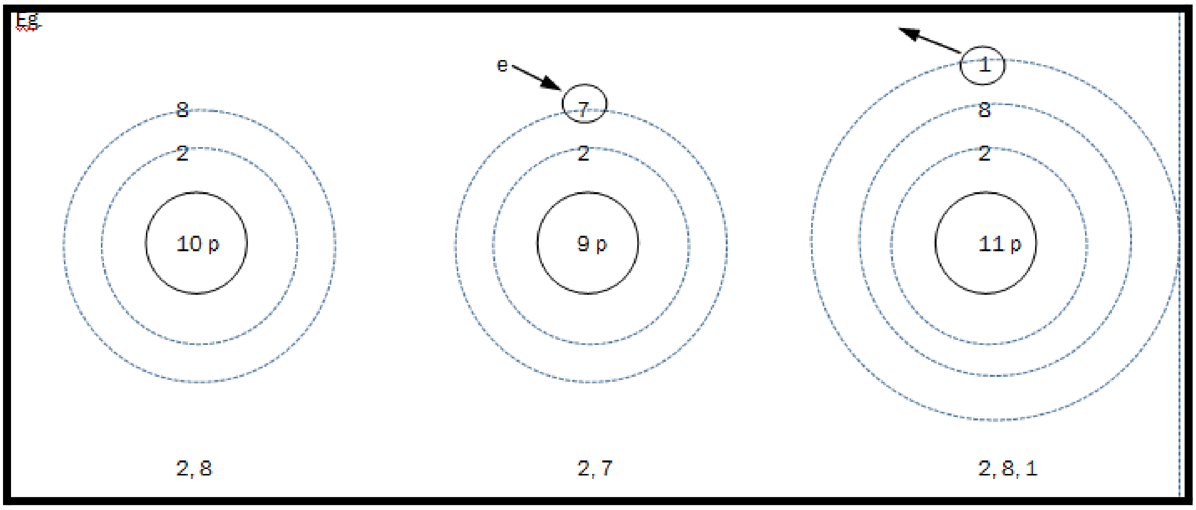
I can investigate the differences between ionic and covalent compounds through using nomenclature, valency and chemical formulae (including Lewis dot diagrams).

Watch video - PSM#22 Ionic and covalent bonding

Properties and Structures of Matter

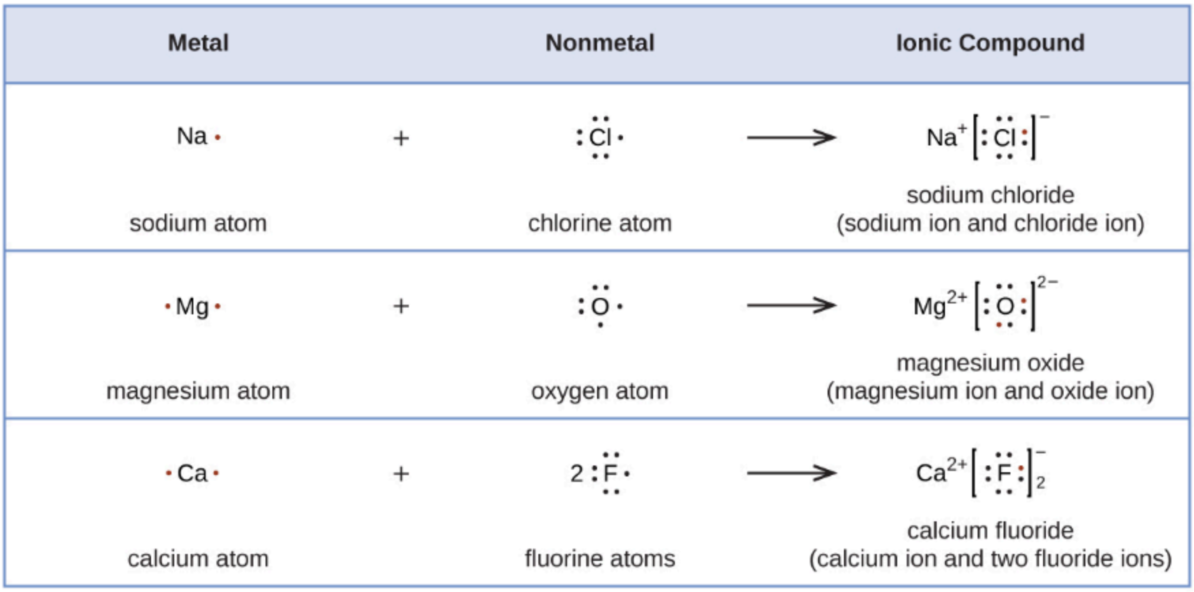
PSM#22 Ionic and covalent bonding

Ionic Compounds



This is neon. It is a stable atom. It does not form an ion.	This is fluorine. It has one less electron than neon. It will gain an extra electron, giving it a negative charge (anion).	This is sodium. It has one more electron than neon. It will lose this extra electron giving it a positive charge (cation).
2.8	2.8	2.8

If a metal bonds with a non-metal, like sodium and oxygen, there is an exchange of electrons and both atoms become charged (ionised). The bond between these two new oppositely charged ions is called an ionic bond. We can also use Lewis diagrams to show how this happens.



https://chem.libretexts.org/Textbook_Maps/General_Chemistry_Textbook_Maps/Map%3A_Chemistry_(OpenSTAX)/07%3A_Chemical_Bonding_and_Molecular_Geometry/7.3%3A_Lewis_Symbols_and_Structures

The periodic table can be used to help us predict which type of ions will form.

+1	+2	+3	±4	-3	-2	-1	0
H							He
Li	Be	B	C	N	O	F	Ne
Na	Mg	Al	Si	P	S	Cl	Ar

If you label every periodic table this way, it may help you during an exam. It provides a quick guide to the types of ions which will form. The transition metals are not included as they are not as straight forward. Many have a valency of +2, however there are exceptions and many species with multiple valencies, eg Fe^{2+} and Fe^{3+}.

Covalent Compounds

What type of bond forms if two non-metals combine together, and they both want to gain electrons, eg. Water (H_2O)?

H (1) + O (2.6) + H (1) → H(2)(2.8)O(2.8)(2)H

This is also easier to see with Lewis diagrams.

In this case, the electrons are shared. It's like there is a tug of war over the electrons (in this case, oxygen would win) because neither the hydrogen nor the oxygen wants to lose any electrons. We can quantify the size of this victory using the differences in electronegativity, as we did in earlier. When they share two electrons, the hydrogen "thinks" it has 2 outer shell electrons (like helium) and the oxygen "thinks" it has 8 outer shell electrons (like neon). So they are both "happy". However, because no electrons have actually gone anywhere, no ions are formed this time.

Despite this, sometimes the oxygen pulls harder on the electrons, becoming temporarily negative, while the hydrogen becomes temporarily positive. At other times the hydrogen pulls harder, so it becomes slightly negative and the oxygen slightly positive. This is a general description and what we will see later is that in the tug of war, there is often one winner and one loser. When this happens the slightly negative or positive nature of the atom remains producing a dipole.

This sharing of electrons between two atoms produces a bond between the atoms called a covalent bond. Covalent bonds form when atoms _ _ _ _ _ electrons.

Properties and Structures of Matter Review Set 21

1. Write the names of three single atom molecules. (3 marks)

   ……………………………………………………………………

   ……………………………………………………………………

2. Identify three molecules which contain more than one atom. (3 marks)

   ……………………………………………………………………………………………

3. Explain how a covalent molecule may be formed. (2 marks)

   ……………………………………………………………………………………………

   ……………………………………………………………………………………………

   ……………………………………………………………………………………………

   ……………………………………………………………………………………………

4. We can use Lewis diagrams to help us understand the differences between ionic and covalent substances in terms of what is happening with the electrons. Draw Lewis diagrams to show the contrasting formation of $MgCl_2$ and PCl_3. (4 marks)

Bonding Spectrum

I can investigate the differences between ionic and covalent compounds through examining the spectrum of bonds between atoms with varying degrees of polarity with respect to their constituent elements' positions on the periodic table.

Watch video – PSM#23 Bonding spectrum

Properties and Structures of Matter

PSM#23 Bonding spectrum

Polarity

For F_2, the fluorine atoms have the same electronegativity value, hence they will each have a 50% share of the electron pair.

For HCl, the Cl is more electronegative than the H. As a consequence it will have > 50% share of the electron pair.

If the imbalance is carried to the extreme (one atom has a 100% share of the electrons) then we have an ionic bond. Few bonds are totally ionic or totally covalent, most have a proportion of each.

Different compounds with a partial ionic character (such as HCl or H_2O) are said to be polar. HCl creates a dipole as the H will be slightly positive and the Cl will be slightly negative.

Properties and Structures of Matter Review Set 22

1. Draw two diagrams to show why we would regard the Cl-Cl bond as non-polar, but the C-Cl bond as polar. Suggest a reason why we would not classify the C-Cl bond as ionic. (5 marks).

   ....

   ....

2.

Shapes of Molecules

I can investigate the differences between ionic and covalent compounds through modelling the shapes of molecular substances.

Watch video – PSM#24 Shapes of molecules

Properties and Structures of Matter

PSM#24 Shapes of molecules

Bonds may be considered to be polar or non-polar and so can molecules. The polarity of a molecule is determined by its shape and or symmetry.

Molecules are non-polar if the sum of their bond dipoles in three dimensions is zero.

Molecules are polar if the sum of their dipoles in three dimensions is non-zero.

Molecules such as F_2 and O_2 are non-polar, because the covalent bonds within the molecules are non-polar. Likewise simple diatomic molecules of compounds, such as HCl will be polar as one atom will always have a larger electronegativity than the other. For larger molecules composed of more than two types of atoms, we must examine the 3-dimensional geometry of the molecules to determine degree of polarity.

We can predict the symmetry of a molecule from a knowledge of the atomic valence orbitals.

The geometrical arrangement of atoms around a central atom is determined by the repulsion of electron pairs in the valence shell of the central atom (VSEPR theory).

The stable arrangement for four pairs of electrons is a tetrahedral shape with bond angles equal to 109^{o} 28′.

- Four bonding pairs eg. methane. Tetrahedral shape, bond angle 109o 28′.

- Three bonding pairs / one non-bonding pair eg. ammonia. Trigonal pyramid shape, H-N-H bond angle 107^{o}.

- Three bonding pairs eg boron triflouride. Trigonal planar shape, F-B-F bond angles 120^{o}.

- Two bonding pairs / two non-bonding pairs eg. water. Bent shape H-O-H bond angle 104^{o} 30′.

There are a few more complex forms (eg trigonal bipyramid – 5 bonding pairs eg PCl_5, and octahedral – 6 bonding pairs eg SF_6), but we won't deal with them at this point in the course as they break our stable octet rules.

Properties and Structures of Matter Review Set 23

1. Show how non-polar molecules like CO_2, may still contain polar bonds. Classify the shape of this molecule. (4 marks)

2. Show how polar molecules like HCN, H_2O and NH_3 have non-zero molecular dipoles. Classify the shapes of these molecules. (10 marks)

3. Covalent Bonds and Shapes of Molecules. Instant Lessons in Chemistry Bk 2, pp. 28-29.

Allotropy

I can investigate elements that possess the physical property of allotropy.

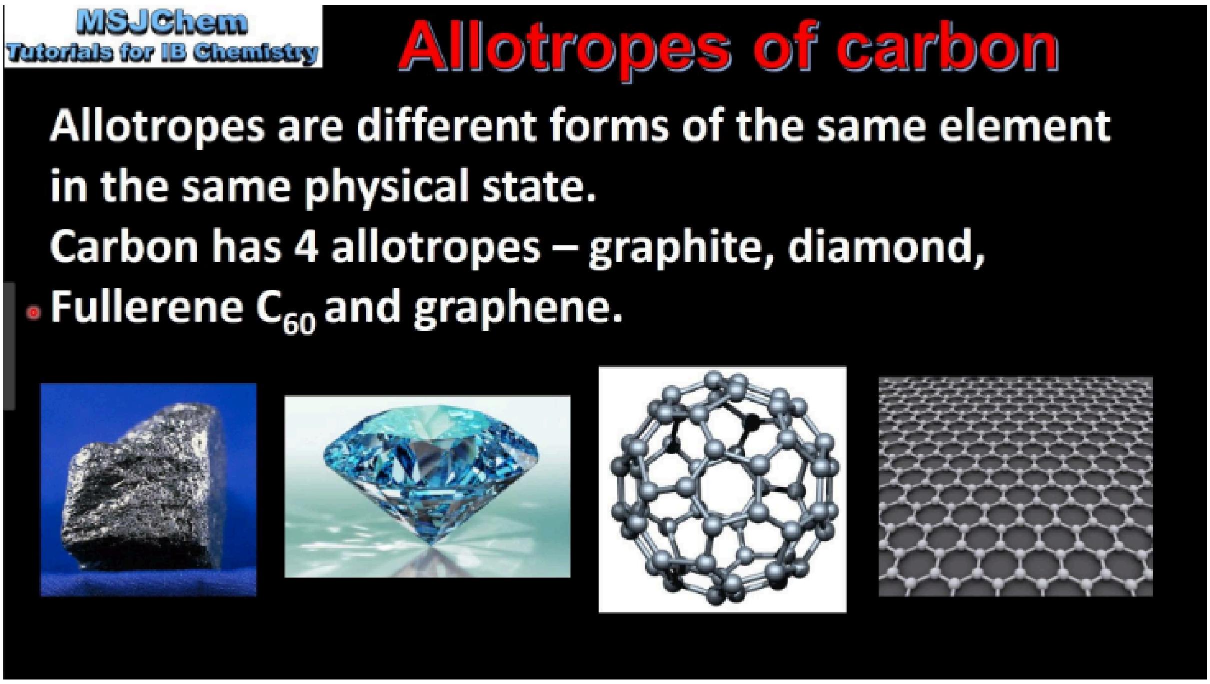
Watch video – PSM#25 Allotropy

Properties and Structures of Matter

PSM#25 Allotropy

Diamond and graphite are different forms of carbon. Two substances with the same chemical formula but which exist in two or more distinctly different forms are called **allotropes**.

Though both substances consist of carbon atoms, the bonding arrangement between the atoms is different and this is what gives diamond and graphite their distinctive physical and chemical properties.



https://i.ytimg.com/vi/XvZmLUGVGW4/maxresdefault.jpg

A third allotrope of carbon exists. It is called fullerene. The most famous fullerene is buckminster fullerine, also known as a bucky ball.

A recent fourth allotrope is being heavily researched. Graphene is an allotrope of carbon which was first isolated in 2004. It consists of a single layer of carbon atoms arranged in an hexagonal lattice. It is wafer thin, incredible strong but flexible and a great conductor and has potential uses in everything from membrane filters through composites to medical applications.

https://image.slidesharecdn.com/graphene-copy-151009161241-lva1-app6892/95/graphene-24-638.jpg?cb=1444407310

Whilst all four allotropes of carbon contain the same types of atom, the arrangement of these atoms is quite different and accounts for the differences we see in their physical properties.

Properties and Structures of Matter Review Set 24

1. Oxygen exists as two gaseous allotropes. Identify these allotropes and draw the structural formula for each allotrope. (4 marks)

2. Sulfur exists in the solid phase in several allotropic forms. Distinguish between two of these allotropic forms. (4 marks)

....

....

Ionic Networks

I can investigate the different chemical structures of atoms and elements, including ionic networks.

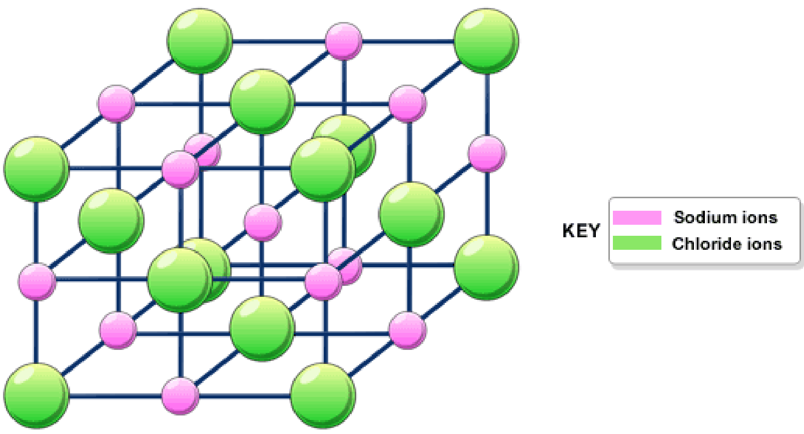
Watch video – PSM#26 Ionic networks

Properties and Structures of Matter

PSM#26 Ionic networks

Opposite charges _ _ _ _ _ _ _

When one chlorine atom accepts one electron from one sodium atom, the chlorine atom becomes a negatively charged ion while the sodium becomes a positive ion. These two ions attract one another. However the chlorine ions will also attract any other positively charged ions and the sodium ion will also attract any other negatively charged ions. The result is a solid network made up of alternating positive and negative charges, as shown below.



http://www.bbc.co.uk/bitesize/higher/chemistry/energy/bsp/revision/3/

Properties and Structures of Matter Review Set 25

1. Ionic compounds are held together by ionic bonds. These are repeating three-dimensional lattices of both positive and negative ions. Construct a ball and stick model, using polystyrene balls and skewers, or other materials, to represent an ionic network. Draw a labelled diagram to demonstrate this in the space below. (3 marks)
2. Begin a comparison table for different atomic arrangements of solids and the relevant physical and chemical properties of each (8 marks)

Structure of solid	Physical properties	Chemical properties
Ionic network		

Covalent Networks

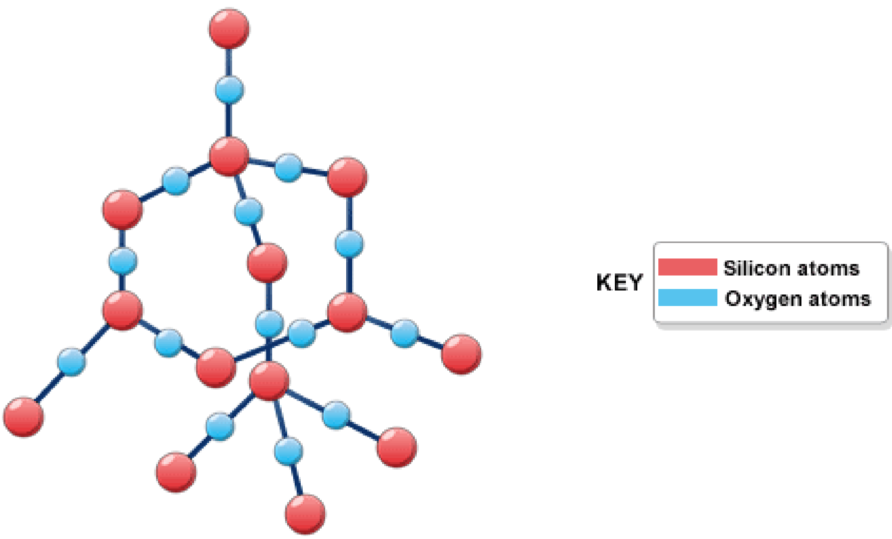
I can investigate the different chemical structures of atoms and elements, including covalent networks (including diamond and silicon dioxide).

Watch video – PSM#27 Covalent networks

Properties and Structures of Matter

PSM#27 Covalent networks

There are two ways in which covalent substances can bond to form solids. One type of covalent structure is the one we see for carbon. Carbon atoms share electrons with 4 other carbon atoms. This gives them great strength and allows them to bond in a continuous array, like those of the ionic networks.



http://www.bbc.co.uk/bitesize/higher/chemistry/energy/bsp/revision/3/

Properties and Structures of Matter Review Set 26

1. Covalent substances are held together by covalent bonds. They may exist either as discrete molecules or as networks (or lattices). Construct a ball and stick model, using polystyrene balls and skewers, or other materials, to represent a covalent network. Draw two diagrams in the space below to show the difference between these types of covalent arrangements. (4 marks)
2. Complete the column on covalent network solids in your comparison table. See Review Set 25.

Covalent Molecular Substances

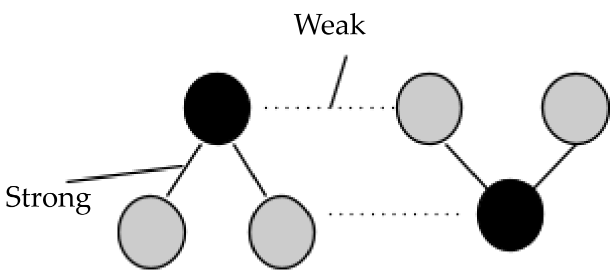
I can investigate the different chemical structures of atoms and elements, including covalent molecular.

Watch video – PSM#28 Covalent molecular solids

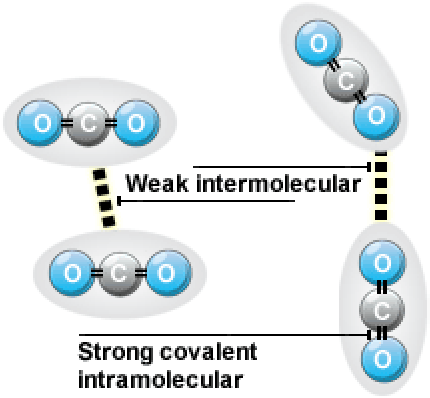
Properties and Structures of Matter

PSM#28 Covalent molecular solids

The second way in which covalent compounds can be organised is the one with which we are most familiar: water, H_2O. Water is a discrete molecule. Even in a solid structure, such as ice, there are discrete molecules of water linked to one another. These substances can readily be melted as the bonds between molecules is much weaker than those within the molecule.



The strong bonds within the molecule are the result of the atoms involved sharing their electrons. The bonds between the molecules are weaker as they are based on the weaker interactions between slightly negative and positive charges created within the molecule.



http://www.bbc.co.uk/bitesize/higher/chemistry/energy/bsp/revision/3/

Properties and Structures of Matter Review Set 27

1. Not only compounds exist as covalent substances. Many elements do too. Identify 4 common elements that exist as discrete molecules and draw the organisation of atoms in a solid in the space below. (8 marks)

2. Construct a ball and stick model, using polystyrene balls and skewers, or other materials, to represent a covalent molecular network. Draw two diagrams in the space below to show the difference between these types of covalent arrangements. (4 marks)

3. Complete the column on covalent molecular solids in your comparison table. See Review Set 25.
4. Worksheet 1.7 The inside story on molecules. Pearson Skills and Assessment pp. 22-23.

Metallic Network

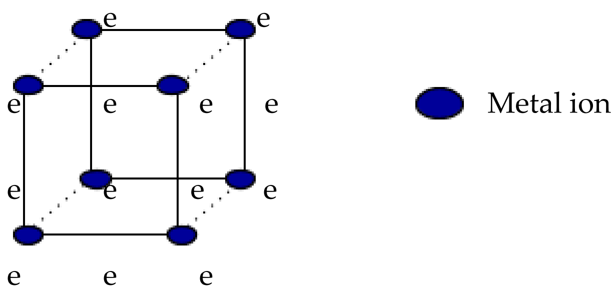
I can investigate the different chemical structures of atoms and elements, including metallic structure.

Watch video – PSM#29 Metallic networks

Properties and Structures of Matter

PSM#29 Metallic networks

Metals are similar to ionic networks. Whilst the do not contain negative ions, the electrons are so loosely held by the individual atoms that they tend to roam around the structure leaving positively charged particles around them. We refer to this structure as islands of positively charged metal ions in a sea of electrons. It has the same type of structure as the ionic network.



The Metallic bond is the electrical attraction between the (+ve) ions and the surrounding 'sea' of negative charges. This bond can be very strong in some metals, so the metal is strong, with a high melting point. (e.g. iron melts around 1500°C) In other metals the bond is weaker, so some metals are softer and melt at lower temperatures. (e.g. lead melts around 320°C)

However, while the metallic bond can be very strong, it is not rigid. The sea of electrons shifts and flows, so the ions can be pushed or pulled to different places without breaking the substance. This is why metals are malleable and ductile, unlike the hard, but brittle ionic or covalent lattices. Metallic lattices are good electrical (solid and molten) and thermal conductors, with high melting and boiling points. They are lustrous and vary in hardness.

Properties and Structures of Matter Review Set 28

1. Metals are held together by metallic bonds. These are networks of positive ions (or a three-dimensional lattice) in a sea of electrons. Make a drawing of a particular metallic lattice. (3 marks)
2. Worksheet 1.5 The inside story on Metals Pearson Skills and Assessment p. 20.

Intermolecular vs intramolecular forces

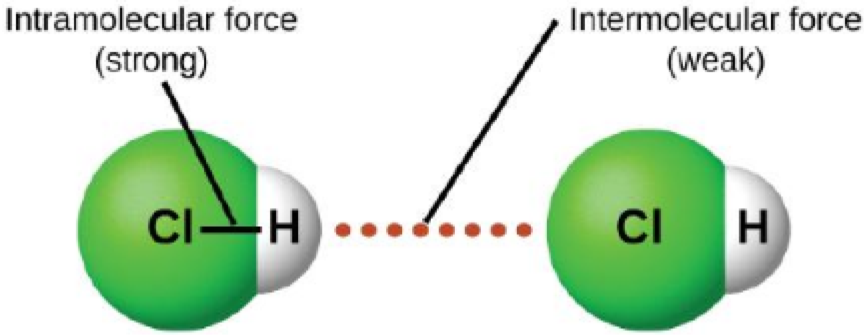
I can explore the similarities and differences between the nature of intermolecular and intramolecular bonds and the strength of the forces associated with each, in order to explain the physical properties of elements.

Watch video – PSM#30 Intermolecular vs intramolecular forces

Properties and Structures of Matter

PSM#30 Intermolecular vs intramolecular forces

Intramolecular forces are the forces involved in chemical bonds, such as ionic and covalent. These are the bonds **within** molecules. They are relatively strong bonds.



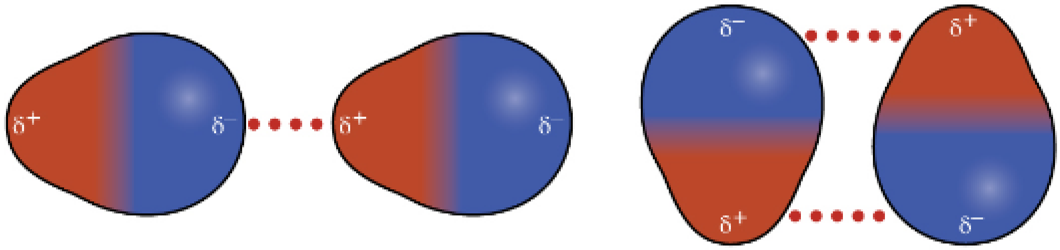
https://chem.libretexts.org/Textbook_Maps/General_Chemistry_Textbook_Maps/Map%3A_Chemistry_(OpenSTAX)/10%3A_Liquids_and_Solids/10.1%3A_Intermolecular_Forces

By contrast, **intermolecular** forces (the forces of attraction **between** molecules) are weaker. They are not chemical, but physical bonds, and are the ones affected by physical changes of state. There are three main types:

- dipole-dipole forces.
- dispersion forces (also called van der Waals forces).
- hydrogen bonds.

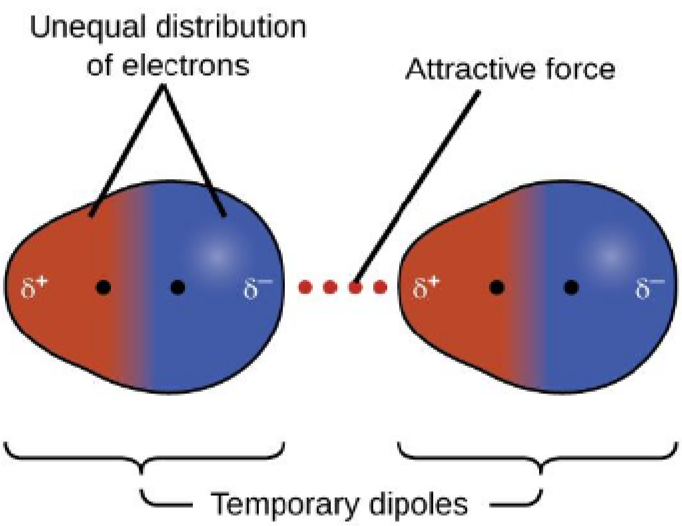
Dipole-dipole forces:

Dipole-dipole forces occur between molecules which themselves are polar, generally polar covalent molecules such as water, and gaseous HCl. Polar bonds are the result of permanent dipole-dipole interactions. They have the effect of raising the relative m. p. and b. p., as they are quite strong forces.



Dispersion forces:

Some covalent substances exist as solids and liquids at room temperature, eg. iodine and bromine. Molecules such as these which are neither ionic, nor polar covalent, still must have some force of attraction holding them together, or they would be gases. These forces are called dispersion forces. They result from temporary induced polarity within the molecules (a result of uneven electron distribution within atoms and between neighbouring atoms and molecules). Whilst there is no permanent polarity, at any given time, the shared electrons may be closer to one atom than the other. During this time, the molecule will have an induced polarity (a temporary dipole or charge separation). Dispersion forces are the result of temporary dipole-dipole interactions. They are generally weaker forces than those induced by polar bonding. Experiments (on boiling points) suggest that larger atoms display stronger dispersion forces than smaller atoms.



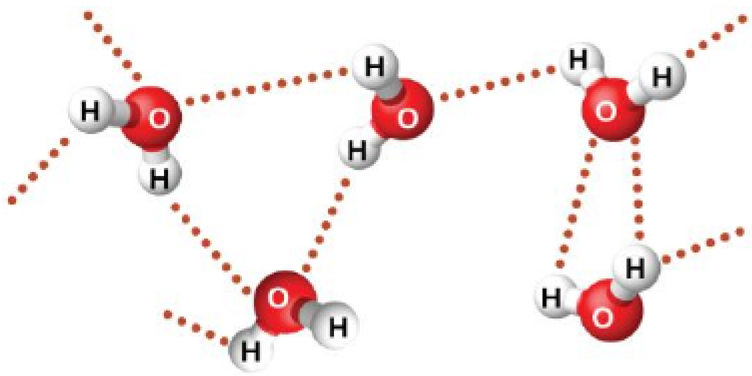
As relative molecular weight increases, so do m. p. and b. p. This is the result of an increase in the attractive strength of the dispersion forces between molecules (extra protons and electrons in the larger atoms.) This has also been observed in polymers (large molecules consisting of long chains of repeating units (monomers). Plastics are a common example of a man-made polymer.

Dispersion forces hold noble gases in the liquid state.

Hydrogen bonds:

Hydrogen bonds are a special case of polar bonds. It involves the bonding of hydrogen to a highly electronegative atom, such as oxygen, nitrogen, chlorine or fluorine. Hydrogen bonding occurs after the hydrogen's electron has bonded with another atom. As a result, the hydrogen becomes slightly positive, attracting the non-bonding electron pair of other atoms through electrostatic forces. Hydrogen bonding is a significant force in molecules such as DNA and proteins.

The bonding in water is strong hydrogen bonding, as this results in waters high b. p. and its ability to dissolve many substances. In ice, the molecules arrange themselves so that the oppositely charged ends line up opposite one another.



The m. p. and b. p. of hydrogen-bonded molecules is quite high relative to other molecules of similar weight.

Properties and Structures of Matter Review Set 29

1. From the following data of m.p., b.p. and electrical conductivity listed in the table below for some elements, predict:

   a) their physical state at SLC, and

   b) whether each is a metal or non-metal.

ELEMENT	Melting point (°C)	Boiling point (°C)	Electrical Conductivity
P	119	445	Poor
Q	1769	3825	Excellent
R	-7	58	Poor
S	30	2400	Very good
T	-219	-183	Poor

(Keep It Simple Science, 2007, p. 11)

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

2. Draw a comparison table to highlight the physical properties of substances which can be linked to their intermolecular and/or intramolecular forces. In your table, include hardness, melting and boiling point and conductivity.

3. 2 Bonding and physical properties. Instant lessons in Chemistry Bk 2 pp. 30-31.

Bond strength and chemical properties

I can explore the similarities and differences between the nature of intermolecular and intramolecular bonds and the strength of the forces associated with each, in order to explain the chemical properties of elements.

Watch video – PSM#31 Bond strength and chemical properties

Properties and Structures of Matter

PSM#31 Bond strength and chemical properties

Now that we know about the intermolecular forces, we can adjust our bond spectrum to reflect the strength of the forces between the molecules.

As we progress along this spectrum, it take more energy to separate the particles (atoms, molecules or ions) from one another. This primarily affects the physical properties, such as melting and boiling point, hardness and conductivity.

However when we put different substances together, it may be possible to completely reorganise the particles to form new arrangements. This is the definition of a chemical process. An understanding of electrostatics – what is happening to the valence shell electrons in particular, can help us predict whether a chemical reaction will take place and what the product(s) of the reaction may be.

Properties and Structures of Matter Review Set 30

1. Explain the particle processes involved in the reaction between hydrogen gas and oxygen gas to form liquid water. (4 marks)

2. Explain the particle processes involved in the reaction between solid calcium and chlorine gas to form solid calcium chloride. (4 marks)

References

Arbor Scientific. (2016). *Exploring Matter: Chemistry Demonstrations*. Retrieved from Arbor Scientific: http://www.arborsci.com/cool/exploring-matter-chemistry-demonstrations/

Aylward, G., & Findlay, T. (2008). *SI Chemical Data* (6th ed.). Milton, Qld: John Wiley & Sons.

Gribben, P. (1999). *Interpreting Data in Chemistry Book 2.* Sydney: Emerald City Books.

Gribben, P. (2010). *Maximising Exam Marks Senior Chemistry Book 1.* Sydney: Blake Education.

Gribben, P., & St Germain, W. (2005). *Assignments in Chemistry Book 2.* Melbourne: Blake Education.

International Union of Pure and Applied Chemistry. (2017). *Nomenclature*. Retrieved from IUPAC: https://iupac.org/what-we-do/nomenclature/

Keep It Simple Science. (2007). The Chemical Earth. Port Macquarie, NSW.

Schell, M., & Molyneux, K. (2007). *Dot Point Preliminary Chemistry.* Sydney: Science Press.

Schell, M., & Molyneux, K. (2010). *Surfing Chemistry Water New Revised Edition.* Sydney: Science Press.

School of Chemistry, University of Sydney. (2014, July 11). *Nomenclature for Inorganic Compounds*. Retrieved from First Year Chemistry: https://scilearn.sydney.edu.au/fychemistry/iChem/inorganic_nomenclature.shtml

Selinger, B. (2002). *Chemistry in the Marketplace* (5th ed.). Sydney: Allen & Unwin.

Smith, R. (2008). *Conquering Chemistry Preliminary Blackline Masters.* Sydney: McGraw-Hill.

Smith, R. (2008). *Conquering Chemistry Preliminary Course Blackline Masters* (2nd ed.). Melbourne: Cengage Learning Australia.

Smith, R. (2010). *Conquering Chemistry Preliminary Course.* Sydney: McGraw-Hill.

Thickett, G. (2007). *Chemistry 1 Preliminary Course.* Brisbane: John Wiley & Sons Australia.

Thickett, G. (2007). *Chemistry 1 Preliminary Course.* Brisbane: John Wiley & Sons.