CHEM110 – Chapter 2
The Language of Chemistry

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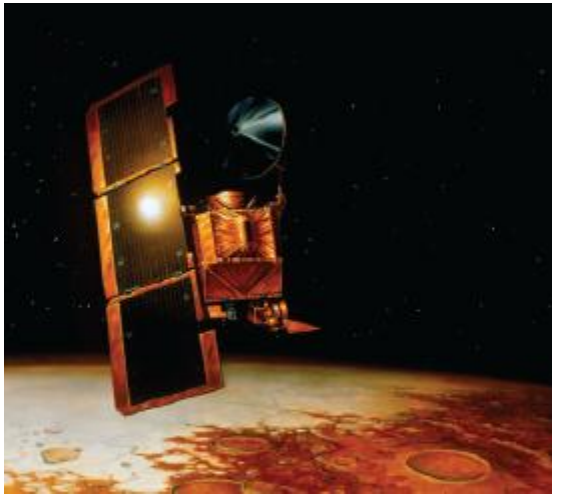
2.1 MEASUREMENT

- **Chemistry is a science of measurement**
  - always has a unit
  - always an associated uncertainty

- **Unit**
  - specific standard quantity of a particular property
  - used to measure all other quantities of specific property

Figure 2.1



2.1 SI UNITS

Measurement	Unit	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
temperature	kelvin	K
amount of substance	mole	mol
electric current	ampere	A
luminous intensity	candela	Cd

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2.1 MEASUREMENT

- **The SI unit for ANY physical quantity can be built from the seven base units**
  - **For example → area = length × width**
    - **length and width are measured in metres**
    - **the unit of area is square metre, m^2**

- **Units undergo the same kinds of mathematical operations as the numbers to which they are attached**

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Worked Example 2.1 - page 26

Deriving SI Units – Heat capacity, which we will in chapter 8, is a measure of the heat required to raise the temperature of a particular substance by 1 K. We can obtain heat capacity values by dividing the heat provided by the temperature change obtained. What is the derived SI unit of heat capacity?

2.1 MEASUREMENT

- **Use prefixes that divide or multiply the unit by a particular power of ten**

Prefix	Symbol	Factor
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
deci	d	10^{-1}

Prefix	Symbol	Factor
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

Worked Example 2.2 - page 27

Using SI Prefixes – Objects that are smaller than about 2×10^{-7} m cannot be seen under an optical microscope. Could you use an optical microscope to observe a virus that is 20 nm long?

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Worked Example 2.3 - page 27

Unit Conversions – The laws of cricket state that a cricket pitch is 22 yards in length. How long is a cricket pitch in metres given that 1 metre = 1.0936 yards?

Dimensional Analysis

- Common question
  - What equations do I need to learn?
- Answer
  - Not many really as you can use **DIMENSIONAL ANALYSIS** to work our the equations for yourself!
- Units undergo the **same kinds of mathematical operations** as the numbers to which they are attached

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Dimensional Analysis

- **Unit of molar mass → g mol^{-1} → obtained by dividing a physical quantity having the unit gram by a physical quantity having the unit mole**

$$\text{molar mass unit (g mol}^{-1}) = \frac{\text{gram}}{\text{mole}} = \frac{\text{mass}}{\text{amount in moles}} = \frac{m}{n}$$

$$\boxed{\text{molar mass} = \frac{m}{n}}$$

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Dimensional Analysis

- **Unit of concentration → mol L^{-1} → obtained by dividing a physical quantity having the unit mole by a physical quantity having the unit litre**

$$\text{concentration (mol L}^{-1}\text{)} = \frac{\text{mole}}{\text{litre}} = \frac{\text{amount in moles}}{\text{volume}} = \frac{n}{V}$$

$$\boxed{\text{concentration} = \frac{n}{V}}$$

Worked Example 2.4 – page 29

Dimensional analysis

An aqueous sugar solution will boil at a temperature slightly greater than 100 °C, depending on how much sugar the solution contains. The magnitude of this boiling point elevation (ΔT) can be calculated from some combination of the molal boiling point elevation constant (K_b) and the molality (b) of the solution. Given that the units of b are mol kg^{-1} and those of K_b are K mol^{-1} kg, what equation should be used to calculate ΔT when this is measured in K?

Analysis

We need to combine the units of b and K_b to give units of K in our final answer. There are three possibilities:

$$\Delta T = \frac{K_b}{b}$$

$$\Delta T = \frac{b}{K_b}$$

$$\Delta T = K_b b$$

We need to determine the final units for ΔT that result from each of these three possibilities. The correct equation will give final units of K.

Worked Example 2.4 – page 29

Solution

We insert the appropriate units into each of the three expressions above.

$$\frac{K_b}{b} \text{ has units of } \frac{\text{K mol}^{-1}\,\text{kg}}{\text{mol kg}^{-1}} = \text{K mol}^{-2}\,\text{kg}^{2}$$

$$\frac{b}{K_b} \text{ has units of } \frac{\text{mol kg}^{-1}}{\text{K mol}^{-1}\,\text{kg}} = \text{K}^{-1}\,\text{mol}^{2}\,\text{kg}^{-2}$$

$$K_b b \text{ has units of K mol}^{-1}\,\text{kg} \times \text{mol kg}^{-1} = \text{K}$$

Therefore, the correct equation to calculate the boiling point elevation is $\Delta T = K_b b$.

Is our answer reasonable?

Given that there is only one way of combining the units of K_b and b to give units of K, we can be confident our answer is correct.

We will learn more about boiling point elevation in chapter 10.

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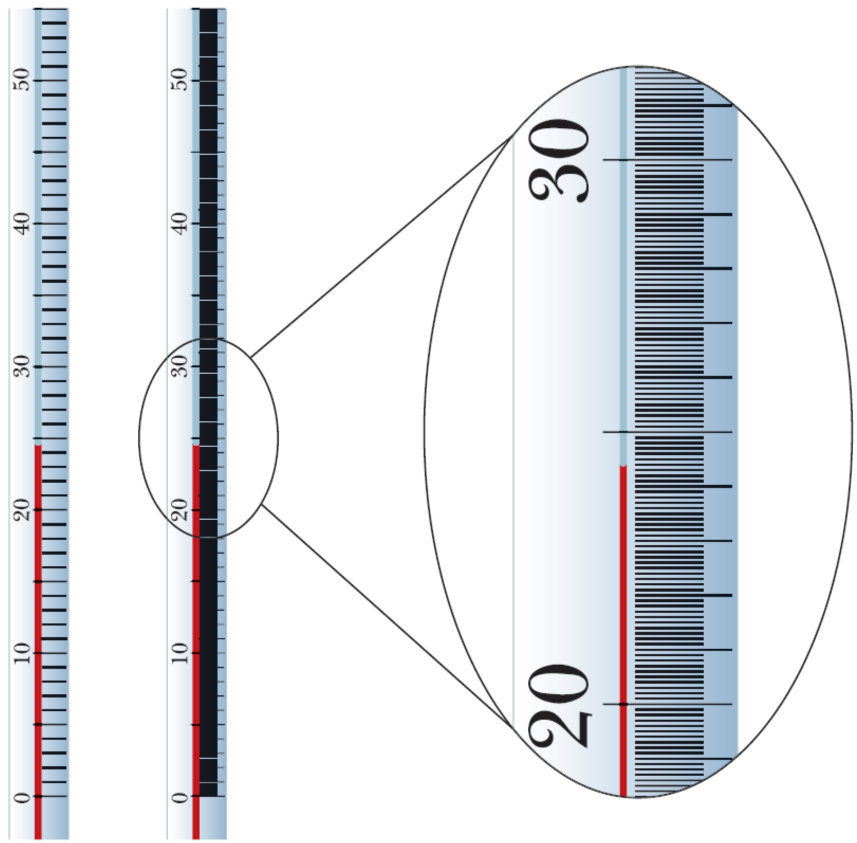
2.1 UNCERTAINTIES and SIGNIFICANT FIGURES

Every measurement has an associated uncertainty

24.3 ºC

297.45 K



24.32 ºC

297.47 K

Figure 2.2

2.1 UNCERTAINTIES and SIGNIFICANT FIGURES

- **All figures in a measurement up to and including the FIRST uncertain number are recorded**
- **These are called SIGNIFICANT FIGURES**
- **There will always be uncertainty in the last significant figure of any measurement**

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2.1 UNCERTAINTIES and SIGNIFICANT FIGURES

- **If you make the measurement → you know how many significant figures**
- **If you are given a measurement → it can sometimes be slightly tricky!**
- **Zero’s can pose a problem!**

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2.1 UNCERTAINTIES and SIGNIFICANT FIGURES

- Zeros at the end of a number
  - 1500
  - 30.
  - 410.0
  - 2670.000
- Zeros in the middle of a number
  - 3507.2
- Zeros at the beginning of a number
  - 0.0056723
  - 0.2344
  - 0.05075
  - 0.60750

Worked Example 2.5 – page 30

Significant Figures – Determine the number of significant figures in the following numbers.

(a) 0.004136

(b) 0.1060

(c) 10.01

2.1 UNCERTAINTIES and SIGNIFICANT FIGURES

- **Scientific notation expresses numbers in terms of powers of ten**

20.32 → 2.032×10^{1}

15 → 1.5×10^{1}

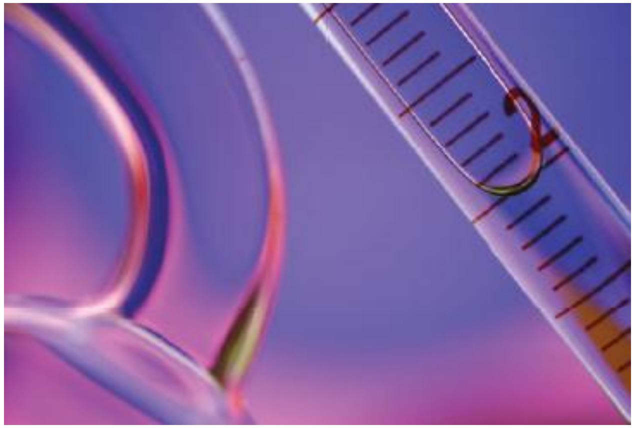
0.0230 → 2.30×10^{-2}

2.1 UNCERTAINTIES

- Uncertainty depends on precision of the instrument
  - 20 mL pipette may have an uncertainty of ± 0.05 mL
  - Quote the pipette as measuring 20.00 ± 0.05 mL
  - Delivers between 19.95 mL and 20.05 mL each time you use it.

- Absolute uncertainty
  - has the same units as the quantity being measured

Figure 2.3



The 0.1 mL graduations in this pipette imply an uncertainty of ± 0.05 mL

2.1 UNCERTAINTIES

$$\text{Percentage uncertainty} = \frac{\text{absolute uncertainty}}{\text{measured quantity}} \times 100\%$$

$$= \frac{0.05\ \text{mL}}{20.00\ \text{mL}} \times 100\%$$

$$= 0.25\%$$

2.1 SIGNIFICANT FIGURES

- Rules for doing calculations to ensure the significant figures in your answer is justified
- Pages 31 – 32
- You must go through them

2.1 SIGNIFICANT FIGURES

- **In calculations**
  - **Multiplication or division of measurements**

$$\frac{3.14 \times 2.751}{0.64} = 13.49709375 = 13$$

  - **Addition or subtraction of measurements**

$$\begin{array}{r} 3.247 \\ 41.36 \\ +125.2 \\ \hline 169.8 \end{array}$$

2.1 SIGNIFICANT FIGURES

- **Rules for doing calculations to ensure the significant figures in your answer is justified**

- **Do Worked Example 2.6 on pages 32-33 and Practice Exercises 2.6 to 2.9 on page 34**

2.1 PRECISION

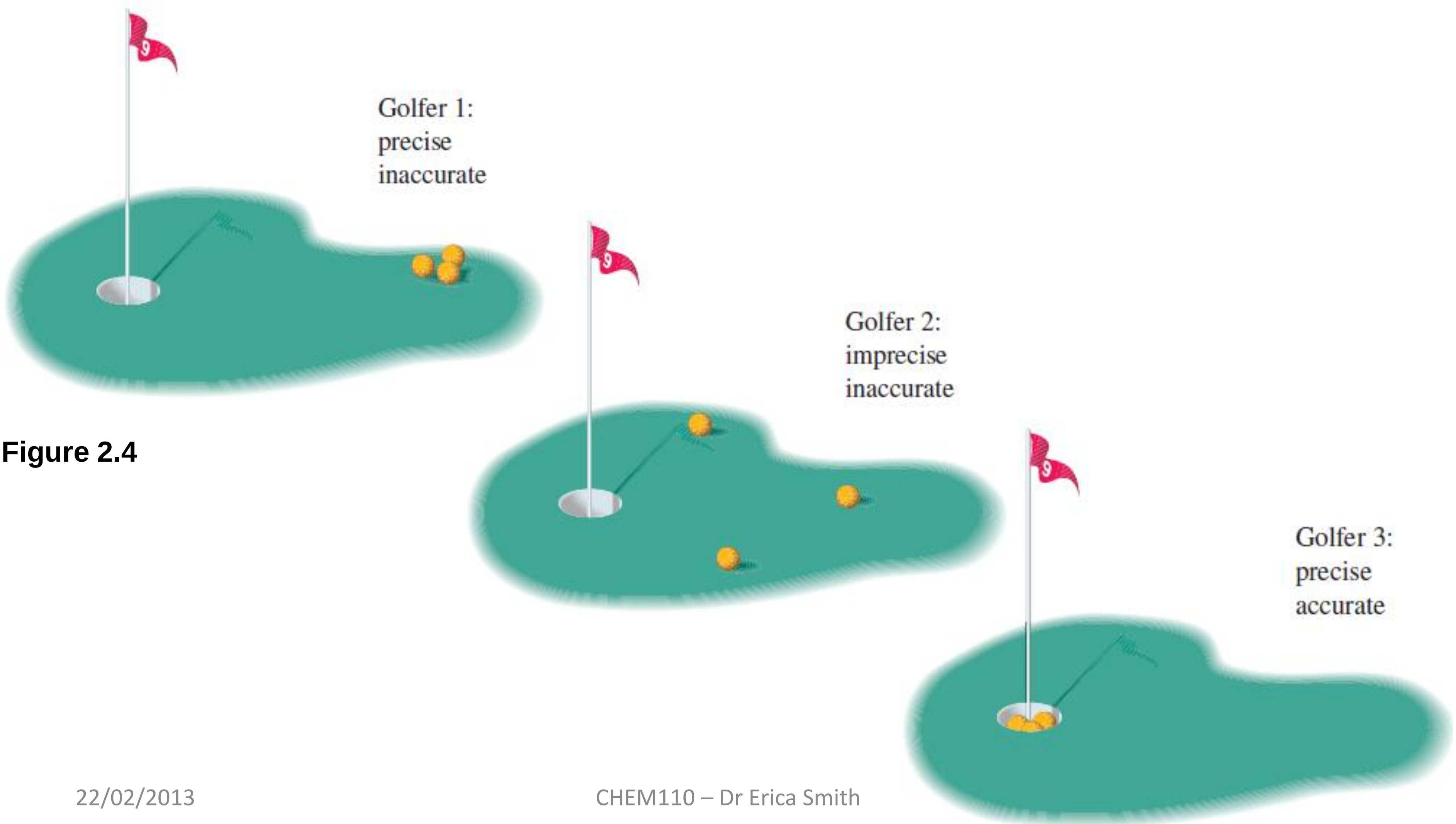


Figure 2.4

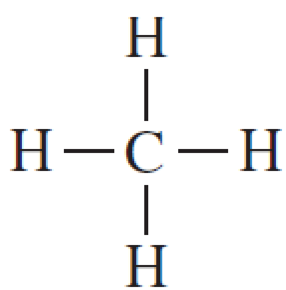
2.2 REPRESENTATIONS of MOLECULES

Figure 2.7

(a) CH_4

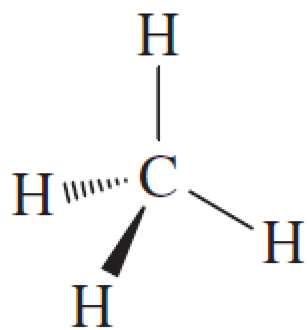
Chemical formula

(b)



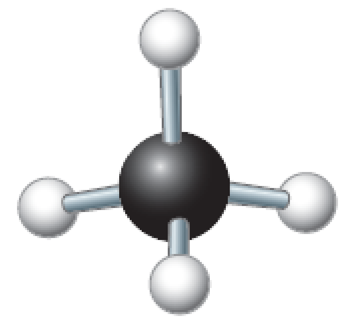
Structural formula

(c)



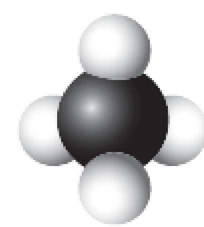
3D structural formula

(d)



Ball-and-stick model

(e)



Space filling model

2.2 CHEMICAL FORMULAE

- Shows the relative number of each type of atom present in a substance
  - H_2O
  - $C_{30}H_{34}AuBClF_3N_6O_2P_2PtW$
  - $B(OH)_3$

- Molecular formula: chemical formula that refers to a discrete molecule

2.2 BINARY COMPOUNDS

- Elements (except H) further to the left of the periodic table appears first e.g. KCl, Al_2S_3
- Hydrogen exception: written last except when with group 16 or 17 e.g. LiH, NH_3, HCl
- If both elements are from the same group the lowest element appears first e.g. SiC, BrF_3
- In ionic compounds the cation is followed by the anion e.g. NaBr, $MgCl_2$

2.2 CHEMICAL FORMULAE

- For compounds containing > 2 elements more knowledge of the bonding is needed

- Ionic compounds
  - Cation followed by anion $Ca(NO_3)_2$
  - Total charge zero $1 \times Ca^{2+}$ $2 \times NO_3^-$
  - Hydrate formation common $Ca(NO_3)_2.4H_2O$

- Covalent compounds
  - carbon first, followed by hydrogen and then the remaining elements in alphabetical order, e.g. C_2H_6O, C_4H_9BrO

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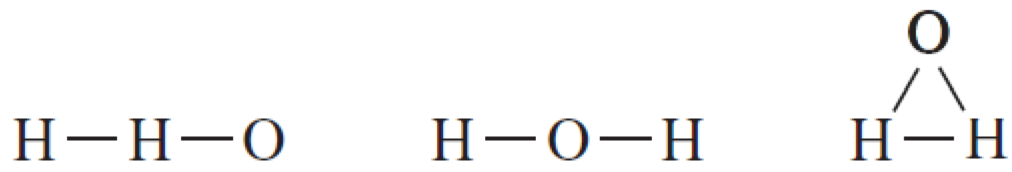
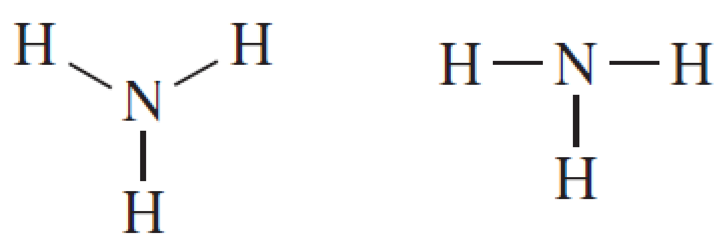
2.2 STRUCTURAL FORMULAE

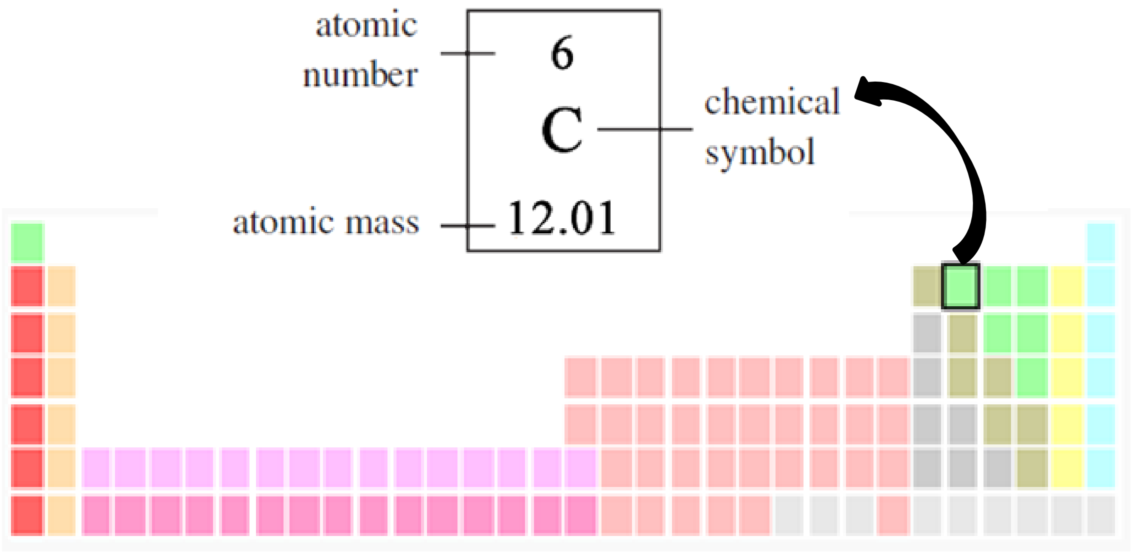
$\boxed{H_2O}$



- **Constituent atoms are placed in the order in which they are bonded together**
- **Bonds between neighbouring atoms are represented as lines**



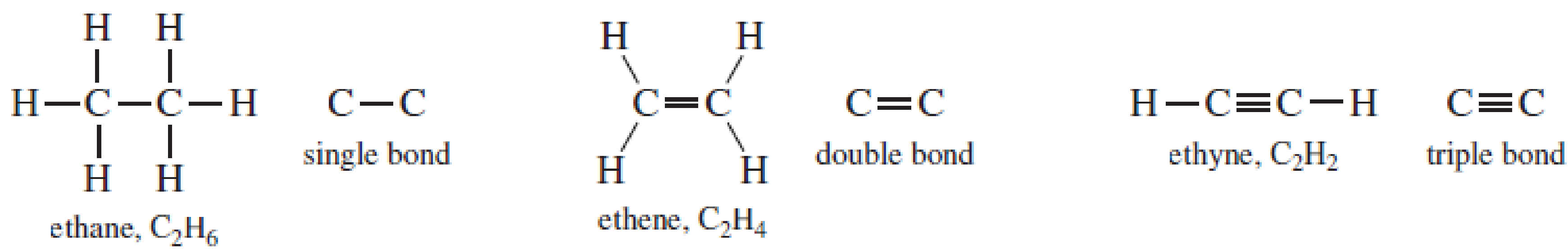
2.2 STRUCTURAL FORMULAE



- Catenation
- Tetravalency

2.2 STRUCTURAL FORMULAE

Figure 2.8



Same chemical formula but different chemical structures → ISOMERS

C_2H_6O

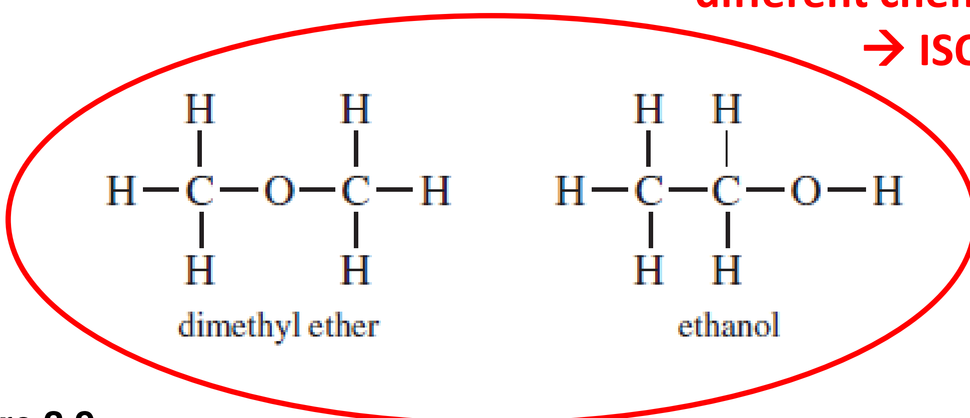


Figure 2.9

2.2 STRUCTURAL FORMULAE

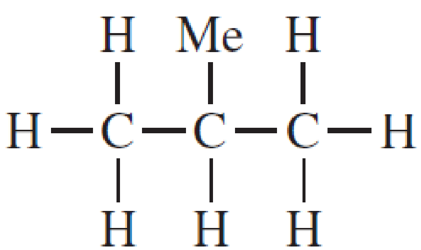
- Two types of shorthand structural formulae
  - Condensed structural formulae
  - Line structures

2.2 STRUCTURAL FORMULAE

- **Condensed structural formulae**
  - Constituent atoms are **arranged in bonded groups** → actual bonds not drawn
    - dimethyl ether CH_3OCH_3
    - ethanol CH_3CH_2OH

$$\left.\begin{array}{l} CH_3OCH_3 \\ CH_3CH_2OH \end{array}\right\} C_2H_6O$$

- $CH_3CH(CH_3)CH_3$
- $(CH_3)_2CHCH_3$
- $(CH_3)_3CH$



Me = methyl, $-CH_3$

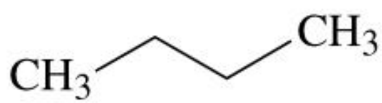
2.2 Representations of molecules

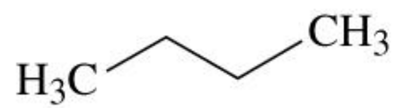
- **Line structures**
  1. **All bonds except C-H bonds are shown as lines**
  2. **C-H bonds and H atoms attached to carbon are NOT shown in the line structure**
  3. **Single bonds are shown as 1 line –**
  4. **Double bonds are shown as 2 lines =**
  5. **Triple bonds are shown as 3 lines ≡**
  6. **Carbon atoms are not labelled, all other atoms are labelled with their elemental symbols**

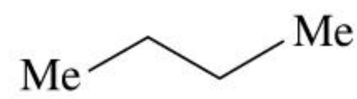
2.2 LINE STRUCTURES

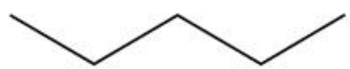
C_3H_8

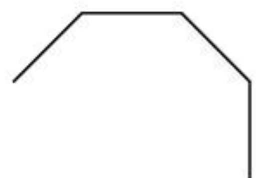
C_4H_{10}

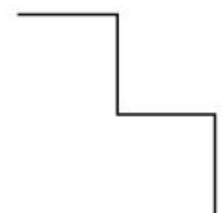




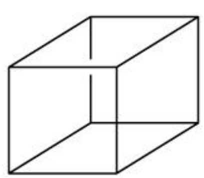




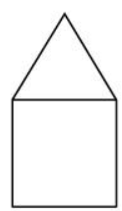




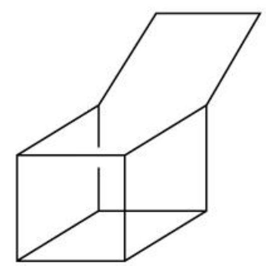
C_5H_{12}



cubane, C_8H_8



housane, C_5H_8



basketane, $C_{10}H_{12}$

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2.2 LINE STRUCTURES

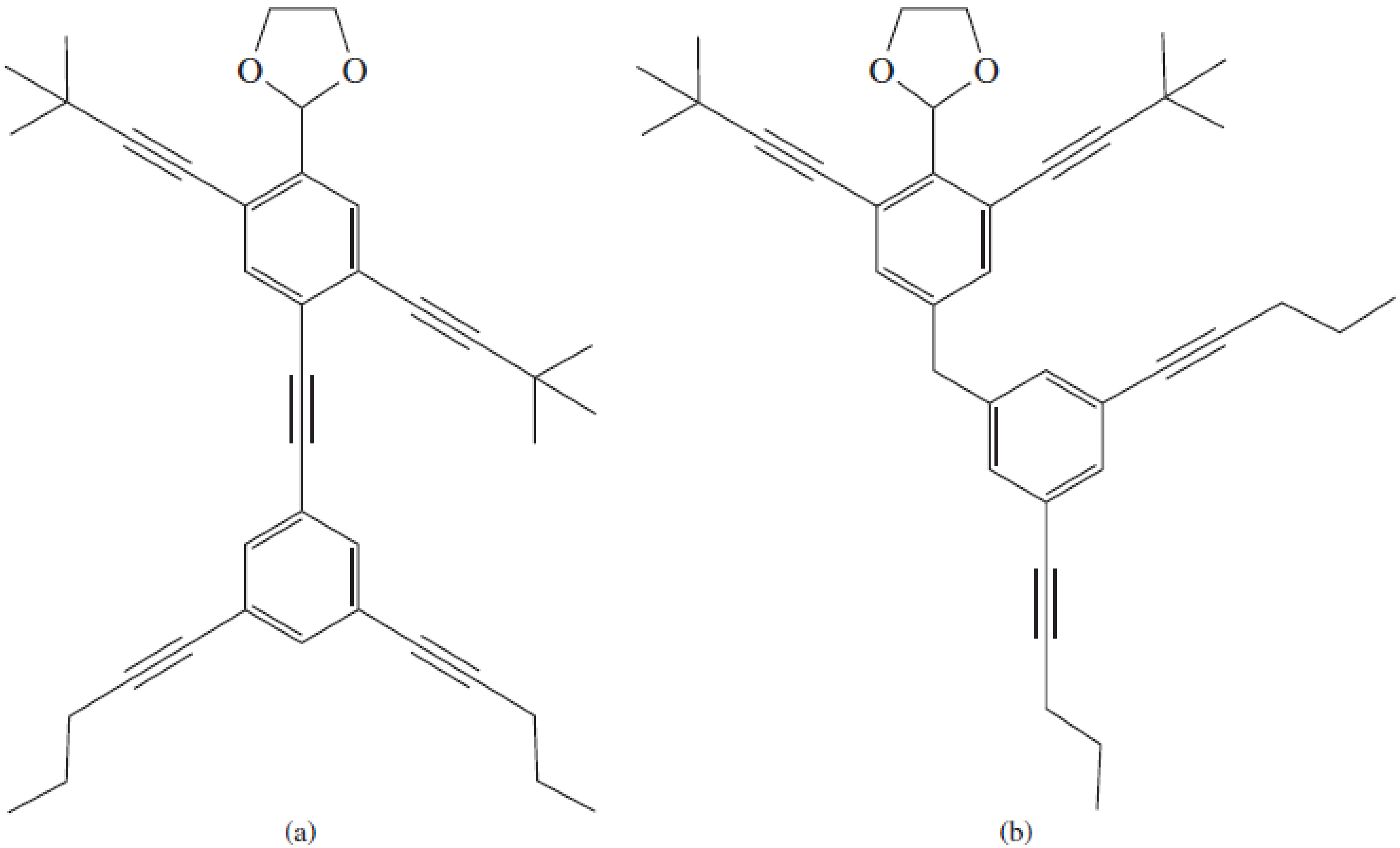

FIGURE 2.10 Line structures of: **(a)** NanoKid **(b)** NanoBalletDancer.

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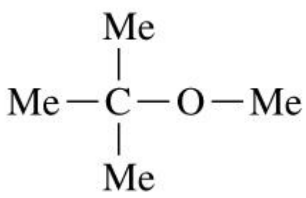
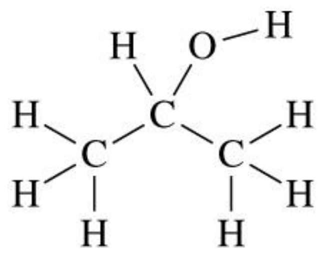
Worked Example 2.7 – page 39

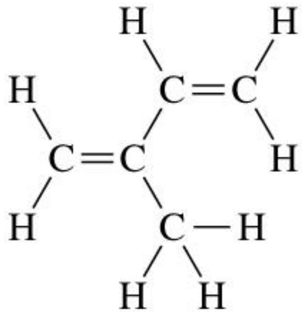
Construct line structures for compounds with the following structural formula.



methyl *tert*-butyl ether
(an antiknock ingredient
in petrol)



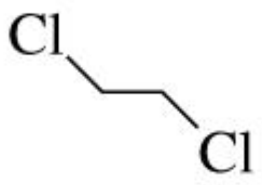
propan-2-ol
(rubbing alcohol)

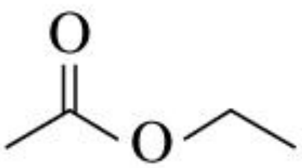


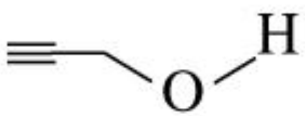
isoprene
(sourced from nature
to produce rubber)

Worked Example 2.8 – page 40

Draw the structural formulae and determine the chemical formulae of the molecules in the following line structures.



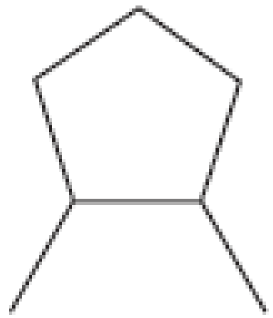




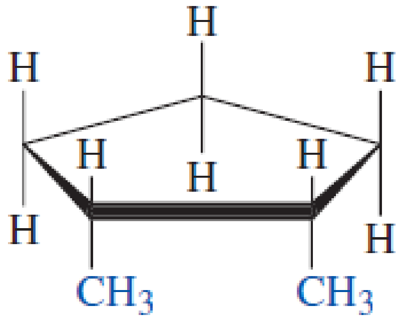
2.2 THREE-DIMENSIONAL STRUCTURES

- Structures so far look "flat"
- Generally molecules are NOT flat!
- Need to include some aspects of three-dimensionality in our representations

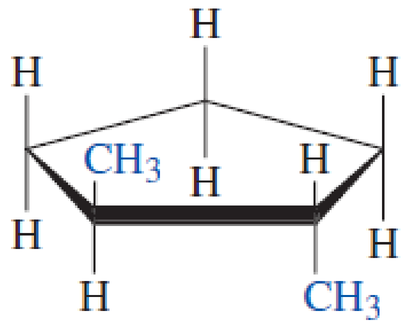
2.2 THREE-DIMENSIONAL STRUCTURES



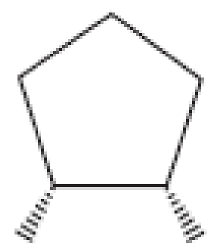
1,2-dimethylcyclopentane



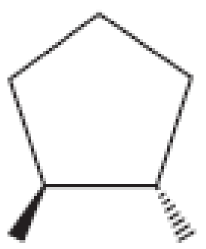
cis isomer



trans isomer

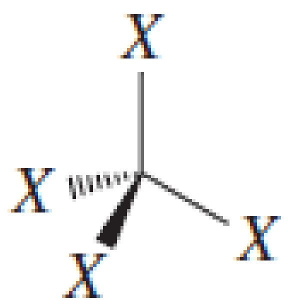


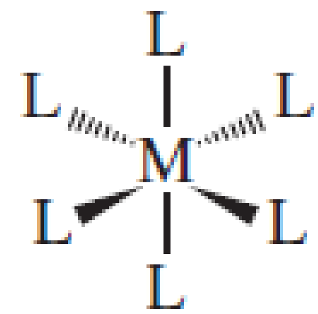
cis isomer



trans isomer

2.2 THREE-DIMENSIONAL STRUCTURES





Tetrahedral

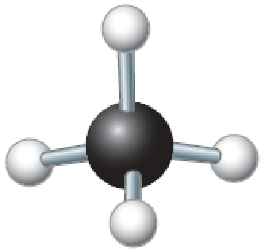
Conventional way to draw 4 bonds around a single carbon atom

Octahedral

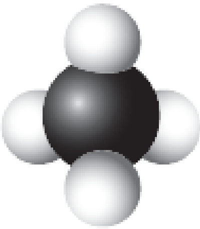
Transition metal ion complex

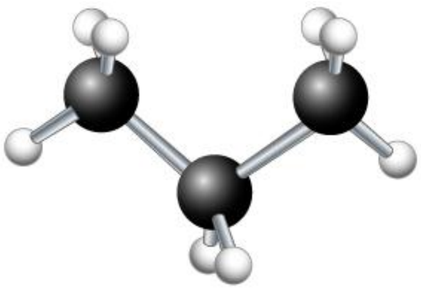
ML_6

2.2 THREE-DIMENSIONAL STRUCTURES

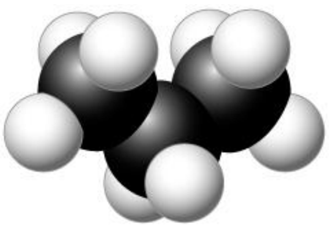


Methane
CH_4





Propane
C_3H_8



Ball-and-stick model

Space filling model

2.2 THREE-DIMENSIONAL STRUCTURES

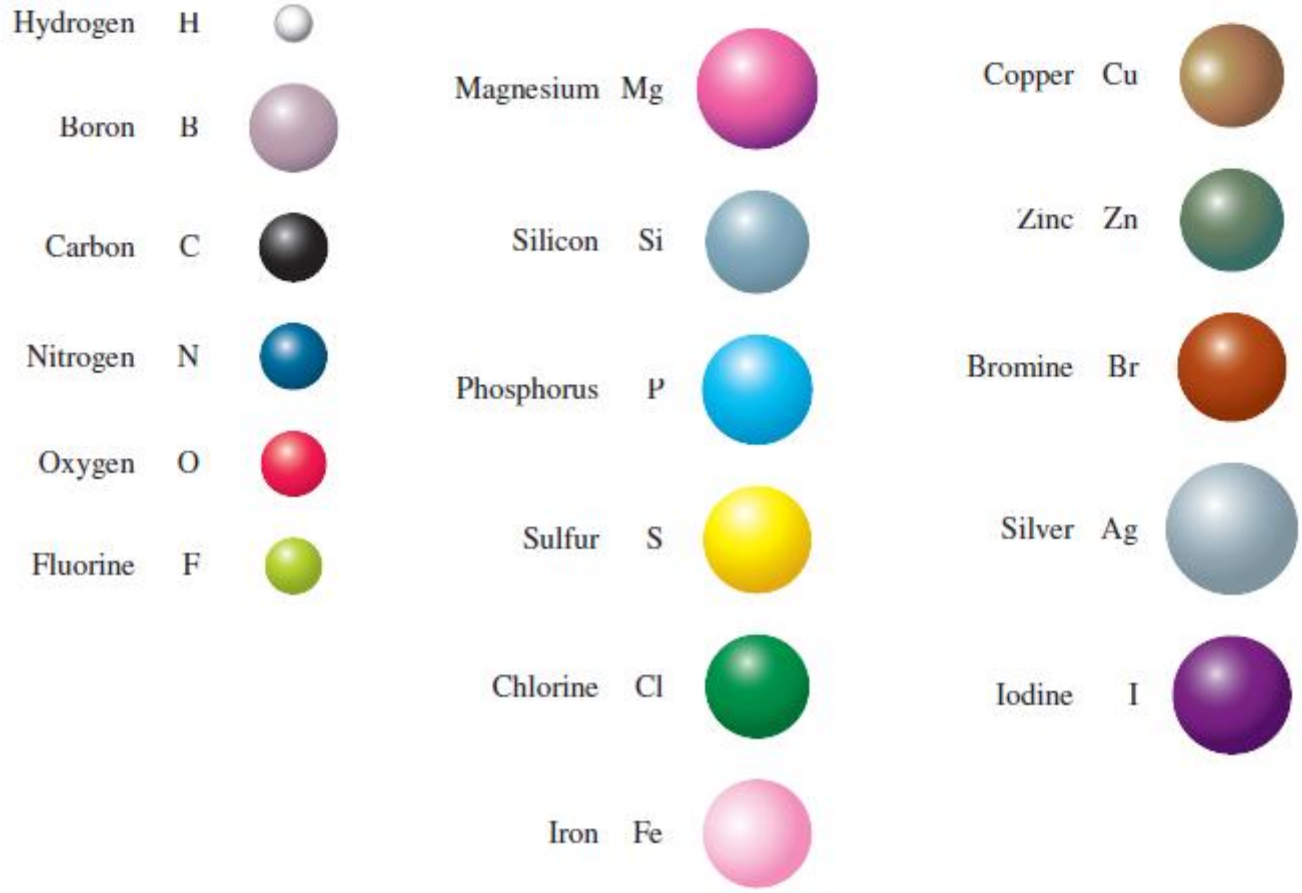


Figure 2.13

2.2 THREE-DIMENSIONAL STRUCTURES

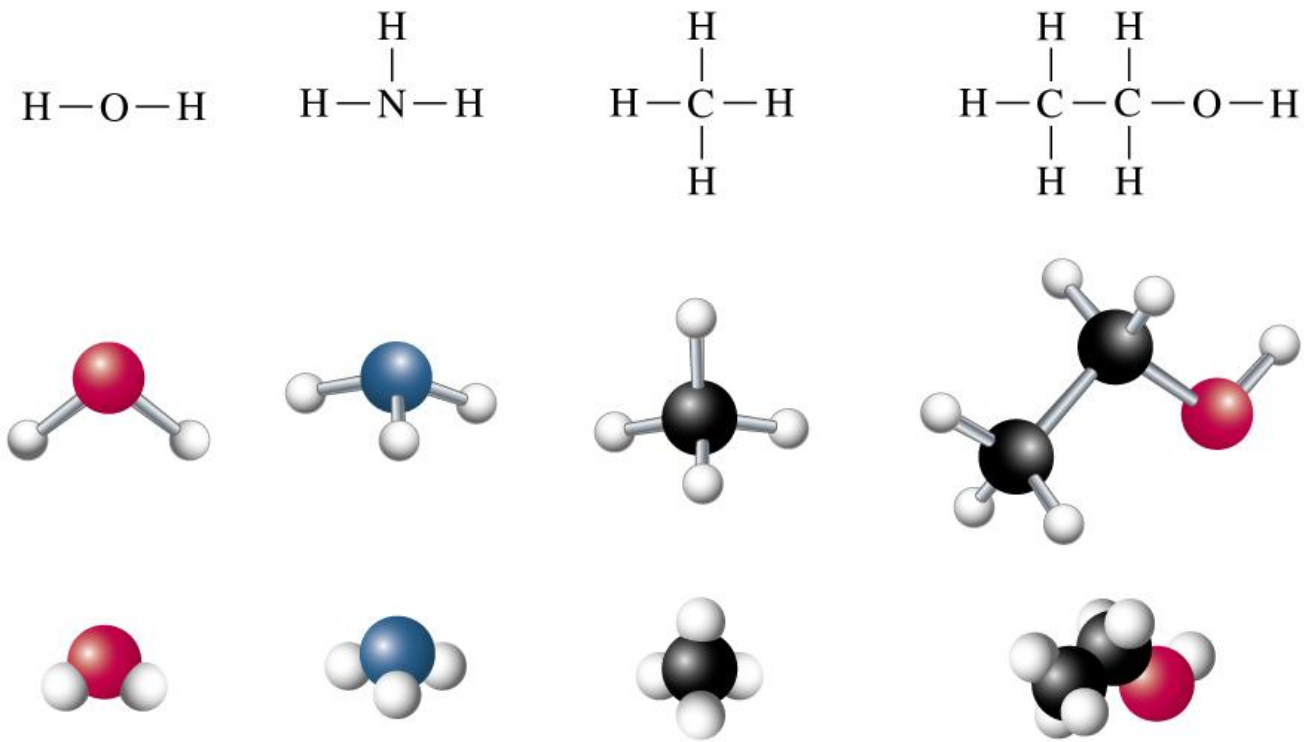
Figure 2.15

Molecule	water	ammonia	methane	ethanol
Chemical formula	H_2O	NH_3	CH_4	C_2H_6O

Structural formula

Ball-and-stick model

Space-filling model



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2.2 THREE-DIMENSIONAL STRUCTURES

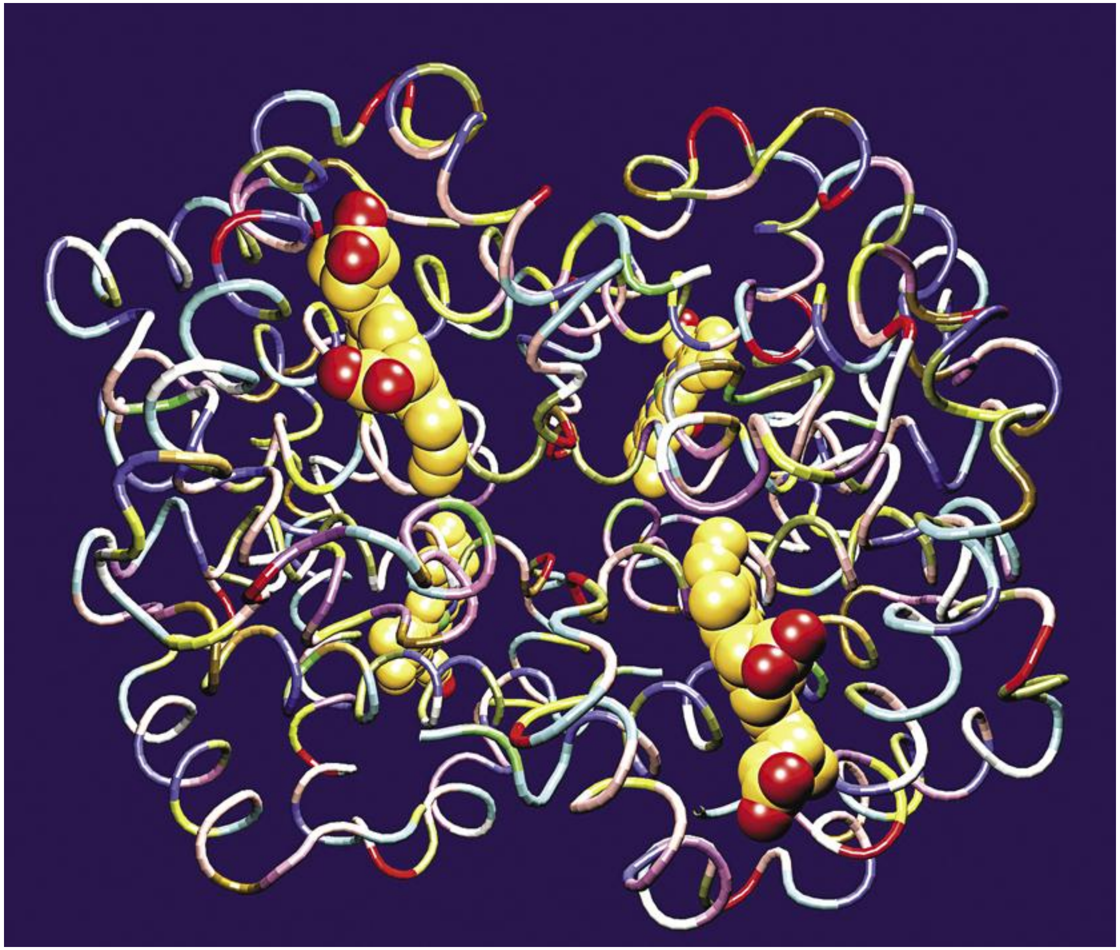

Figure 2.16
A representation of the structure of haemoglobin showing 4 heme groups. The different ribbons denote the different parts of the protein

2.2 THREE-DIMENSIONAL STRUCTURES

Figure 2.17 Representation of deoxyribonucleic acid (DNA) double helix

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2.2 THREE-DIMENSIONAL STRUCTURES

- **In addition to representing structures → also need to depict way chemical bonds break or form**

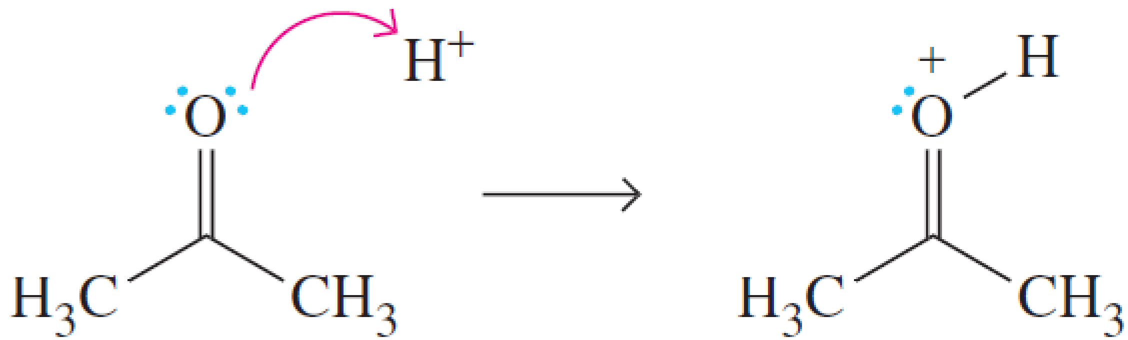
- **Use MECHANISTIC ARROWS**

2.2 THREE-DIMENSIONAL STRUCTURES

- **Bond breaking**

$$H-Cl \longrightarrow H^+ + Cl^-$$

- **Bond making**



- **Charge neutralisation**