

# Worksheet 1.1: Elements, compounds and mixtures and kinetic molecular theory

1

	Element	Compound	Mixture
Coffee			✓
Tungsten	✓		
Steam		✓	
Crude oil			✓
Sulfur trioxide		✓	
Bromine	✓		
Air			✓
Zinc chloride		✓	
Pure ethanol		✓	
Phosphoric acid			✓

- 2
- a  $\text{Na(s)} + 2\text{H}_2\text{O(l)} \rightarrow 2\text{NaOH(aq)} + \text{H}_2\text{(g)}$
- b  $\text{I}_2\text{(s)} \rightarrow \text{I}_2\text{(g)}$
- c  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O(s)} + \text{H}_2\text{O(l)} \rightarrow \text{CuSO}_4\text{(aq)}$  Note: this is not a balanced equation.
- d  $\text{AgNO}_3\text{(aq)} + \text{NaCl(aq)} \rightarrow \text{AgCl(s)} + \text{NaNO}_3\text{(aq)}$

- 3 Set up a filter with filter paper inside. Place it on top of a mug.

Add ground coffee to the filter paper.

Pour hot water onto the coffee powder slowly. The hot water is the solvent, and it will dissolve the soluble part of the ground coffee, the solute, to form a solution. The filtrate will go through the filter into the mug. The insoluble part of the coffee will stay on the filter paper as a residue. The process of dissolving the coffee is called solvation.

- 4 Carbon dioxide sublimates at room temperature and pressure. The kinetic energy of the particles increases during this process. The particles become further apart as the intermolecular forces are broken, and the particles move faster and more randomly. Note, students could also comment on the process of condensation of water vapour.

- 5 Step 1:** Sodium carbonate reacts with the propanoic acid and the concentrated sulfuric acid. The products are soluble salts and are dissolved in the aqueous phase.
- Step 2:** The aqueous layer contains the salts from the reactions of sodium carbonate with the acids and the remaining methanol. These are now removed.
- Step 3:** The anhydrous calcium chloride combines with any water remaining in the ester phase.
- Step 4:** The solid and hydrated calcium chloride are removed by filtration.
- Step 5:** The boiling point of methyl propanoate is  $80^{\circ}\text{C}$ , so the fraction was distilled between  $79$  and  $81^{\circ}\text{C}$ .

# Worksheet 2.1: The atomic structure

1

Symbol	p	n	e
$^{10}\text{Be}$	4	6	4
$^{18}\text{O}^{2-}$	8	10	10
$^{33}\text{P}$	15	18	15
$^{45}\text{Sc}^{3+}$	21	24	18
$^{59}\text{Co}$	27	32	27
$^{80}\text{Br}^{-}$	35	45	36
$^{87}\text{Sr}$	38	49	38
$^{118}\text{Sn}^{4+}$	50	68	46
$^{131}\text{Xe}$	54	77	54
$^{207}\text{Pb}^{2+}$	82	125	80

2

Symbol	p	n	e
HCl	18	18	18
$\text{OH}^{-}$	9	8	10
$\text{NH}_3$	10	7	10
$\text{SO}_4^{2-}$	48	48	50
$\text{PCl}_3$	66	70	66
$\text{NO}_2^{+}$	23	23	22
$\text{BeCl}_2$	38	41	38
$\text{CN}^{-}$	13	13	14
$[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$	86	78	83
$[\text{CuCl}_4]^{2-}$	97	106	99

- 3 a 10.8 to 3 significant figures  
b 62.5%

# Worksheet 3.1: Electron configuration

1

	Full electron configuration	Condensed electron configuration
B	$1s^2 2s^2 2p^1$	$[\text{He}] 2s^2 2p^1$
S	$1s^2 2s^2 2p^6 3s^2 3p^4$	$[\text{Ne}] 3s^2 3p^4$
Cr	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$	$[\text{Ar}] 4s^1 3d^5$
Cu	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$	$[\text{Ar}] 4s^1 3d^{10}$
Ge	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^2$	$[\text{Ar}] 4s^2 3d^{10} 4p^2$

2

	Full electron configuration	Condensed electron configuration
$\text{N}^{3-}$	$1s^2 2s^2 2p^6$	$[\text{Ne}]$
$\text{S}^{2-}$	$1s^2 2s^2 2p^6 3s^2 3p^6$	$[\text{Ar}]$
$\text{Ti}^{4+}$	$1s^2 2s^2 2p^6 3s^2 3p^6$	$[\text{Ar}]$
$\text{Co}^{2+}$	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$	$[\text{Ar}] 3d^7$
$\text{Rb}^+$	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$	$[\text{Kr}]$

3

Electron configuration	Symbol
$1s^2 2s^2 2p^5$	F
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$	K
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5$	Mn
$[\text{Ne}] 3s^2 3p^2$	Si
$[\text{Ar}] 4s^2 3d^{10} 4p^4$	Se

4

Transitions	Electromagnetic radiation
$n = 3 \rightarrow n = 1$	UV
$n = 6 \rightarrow n = 2$	visible
$4p \rightarrow 3s$	infrared
$5d \rightarrow 2p$	visible
$3d \rightarrow 1s$	UV

# Worksheet 3.2: Hydrogen emission spectrum

In a hydrogen emission spectrum, there are separate **lines** representing radiations of different **energies or frequencies or wavelengths**. The presence of a **line** spectrum rather than a **continuous** spectrum provides evidence that electrons can only possess certain allowed energies in an atom.

The emission spectrum is produced when an electron is **excited** by external energy and moves from its **ground** state to a **higher** energy level. When the electron returns to a **lower** energy level, a photon of a particular energy is released. The energy of the light is equal to the **difference** between the two energy levels.

There are different **series** of lines in the hydrogen emission spectrum. The Lyman series in the UV region is produced when the **excited** electron returns to the  $n = 1$  level, where  $n$  represents the **main** energy level. The Balmer series in the visible region is produced when the **excited** electron returns to the  $n = 2$  level.

The lines in the emission spectrum get **closer** at higher energy; this means the **energy levels** in an atom get closer at higher **energy or frequency**.

# Worksheet 4.1: Calculations involving the amounts of substances

- 1**
- a** 0.0751
  - b** 433 000
  - c** 19 900
  - d** 0.084
  - e** 604
  - f** 2350
  - g** 0.00041
  - h** 0.0100
  - i** 6.7225
  - j** 25.522
- 2**
- a**  $1.81 \times 10^{24}$
  - b**  $1.20 \times 10^{21}$
  - c**  $9.03 \times 10^{23}$
  - d**  $5.78 \times 10^{25}$
  - e**  $6.02 \times 10^{22}$
  - f**  $6.02 \times 10^{23}$
  - g**  $1.44 \times 10^{26}$
  - h**  $3.01 \times 10^{20}$
  - i**  $1.20 \times 10^{23}$
  - j**  $1.20 \times 10^{23}$
- 3**
- a** 441.1 g
  - b** 0.100 g
  - c** 0.07902 g
  - d**  $7.65 \times 10^{-23}$  g
  - e**  $3.20 \times 10^{-21}$  g

- 4**   **a** 0.21195 g  
      **b** 270.12 g  
      **c** 4 g  
      **d** 6.019 g  
      **e**  $6.292 \times 10^{-4}$  g

# Worksheet 4.2: Practical sheet on an experiment to determine the empirical formula of magnesium oxide

## Analysis of results

- 1 Examples of observations: magnesium glows when the crucible lid is lifted; some white smoke escapes; magnesium is dull on its surface at the beginning of the experiment; there is some grey solid mixed with the white powdery products.

- 2 An example of trial data:

Mass of crucible + lid / $\pm 0.01$ g	36.71
Mass of magnesium + crucible + lid / $\pm 0.01$ g	37.86
Mass of product + crucible + lid / $\pm 0.01$ g	38.37

- 3 An example of trial data:

mass of magnesium =  $37.86 - 36.71 = 1.15$  g

moles of magnesium =  $1.15 / 24.31 = 0.0473$  mol

mass of oxygen =  $38.37 - 37.86 = 0.51$  g

moles of oxygen =  $0.51 / 16.00 = 0.0319$  mol

simplest whole number ratio of moles of Mg to O  $\approx 3:2$

The empirical formula is  $\text{Mg}_3\text{O}_2$ .

## Evaluation of experiment

- 4 The lid is lifted to allow oxygen to enter the crucible and react with the magnesium.  
The lid should not be left off for a long time as too much of the product (white smoke) will escape.
- 5 To ensure that all the magnesium has reacted with oxygen, so there is no more increase in mass.
- 6 Possible systematic errors: 1) Magnesium is already oxidised on its surface at the beginning of the experiment, so less oxygen would be added. 2) Some product escapes during the experiment, so the mass of magnesium oxide measured at the end is less than it should be. 3) Not all magnesium has reacted with oxygen. 4) Magnesium can react with nitrogen in the air, forming other products.
- 7 An example of trial data from question 2:  
% uncertainty =  $0.02 / 1.15 \times 100\% = 1.74\%$   
  
this is smaller than the percentage error in the empirical formula (the calculated ratio of moles of Mg to O is 3 : 2 rather than 1 : 1 from literature). The percentage uncertainty in the mass measurement is small and acceptable, and there is no need for a more precise balance to be used.



# Worksheet 5.1: Ideal gas calculations

- 1 a 1130  
 b  $-192.15$   
 c 67 000  
 d 35  
 e 1
- 2 a  $1.20 \times 10^{20}$   
 b  $3.01 \times 10^{24}$   
 c  $1.00 \times 10^{27}$   
 d  $2.11 \times 10^{21}$   
 e  $3.01 \times 10^{21}$

3

Gas	$P_1$	$V_1$	$T_1$	$P_2$	$V_2$	$T_2$
A	100 kPa	50 cm <sup>3</sup>	26.85°C	100 kPa	66.7 cm <sup>3</sup>	126.85°C
B	$3.5 \times 10^4$ Pa	250 cm <sup>3</sup>	19.85°C	$8.75 \times 10^4$ Pa	200 cm <sup>3</sup>	312.85°C
C	0.5 bar	15 dm <sup>3</sup>	450 K	0.75 bar	10 dm <sup>3</sup>	450 K
D	1 atm	50 m <sup>3</sup>	200 K	0.625 atm	100 cm <sup>3</sup>	250 K
E	$1.8 \times 10^5$ Pa	$2.5 \times 10^{-2}$ dm <sup>3</sup>	-23.15°C	$5 \times 10^5$ Pa	$1.2 \times 10^{-2}$ dm <sup>3</sup>	60.2°C or 333 K

# Worksheet 5.2: Practical sheet on an experiment to determine the $A_r$ of lithium

## Analysis of results

- 1 Examples of observations: lithium is black on its surface when it is taken out of oil storage; some gas escapes between adding lithium and replacing the bung on the conical flask; lithium decreases in size and disappears; lithium effervesces; the reaction is exothermic and the conical flasks gets warmer during the experiment.

- 2 An example of trial data:

	Data	Absolute uncertainties
mass of lithium (g)	0.11	$\pm 0.01$
pressure in the lab (mmHg)	754.0	$\pm 0.5$
room temperature ( $^{\circ}\text{C}$ )	19.0	$\pm 0.5$
initial volume of $\text{H}_2$ (millilitres)	0.0	$\pm 0.5$
final volume of $\text{H}_2$ (millilitres)	172.0	$\pm 0.5$
volume of $\text{H}_2\text{O}$ in conical flask (millilitres)	100	$\pm 30$

- 3 pressure = 754.0 mmHg = 1 00 525 Pa

temperature = 19.0  $^{\circ}\text{C}$  = 292.15 K

volume of  $\text{H}_2$  produced = 172 millilitres

no. of moles of  $\text{H}_2$  =  $PV / RT = (1\,00\,525 \times 172 / 1\,000\,000) / (8.31 \times 292.15) = 7.12 \times 10^{-3}$  mol

no. of moles of lithium =  $2 \times 7.12 \times 10^{-3} = 0.0142$  mol

$A_r$  of lithium =  $0.11 / 0.0142 = 7.72$

- 4 The percentage uncertainty in the  $A_r$  of lithium = the percentage uncertainty in pressure + the percentage uncertainty in temperature in kelvin + the percentage uncertainty in volume of gas + the percentage uncertainty in mass of lithium.

This can then be converted back to the absolute uncertainty ( $U$ ) in the  $A_r$  of lithium to one significant figure.

conversion of pressure involves multiplication  $\rightarrow$  %  $U$  in pressure in Pa = %  $U$  in pressure in mmHg =  $0.5 / 754.0 \times 100\% = 0.0663\%$

conversion of temperature involves addition  $\rightarrow$  absolute  $U$  in  $T$  in K = absolute  $U$  in  $T$  in  $^{\circ}\text{C}$  = 0.5  $\rightarrow$  %  $U$  in  $T$  in K = 0.171%

volume of  $\text{H}_2$  = 172 millilitres  $\pm 1 \rightarrow$  %  $U$  in  $V$  in millilitres = 0.581% = %  $U$  in  $V$  in  $\text{m}^3$

%  $U$  in no. of moles of  $H_2$  = %  $U$  in  $P$  + %  $U$  in  $V$  + %  $U$  in  $T$  = 0.819% = %  $U$  in no. of moles of Li

%  $U$  in mass of Li = 9.09%

%  $U$  in no. of moles of Li = 9.91%

absolute  $U$  in  $A_r$  of Li =  $9.91 / 100 \times 7.72 = 0.8$  to one significant figure

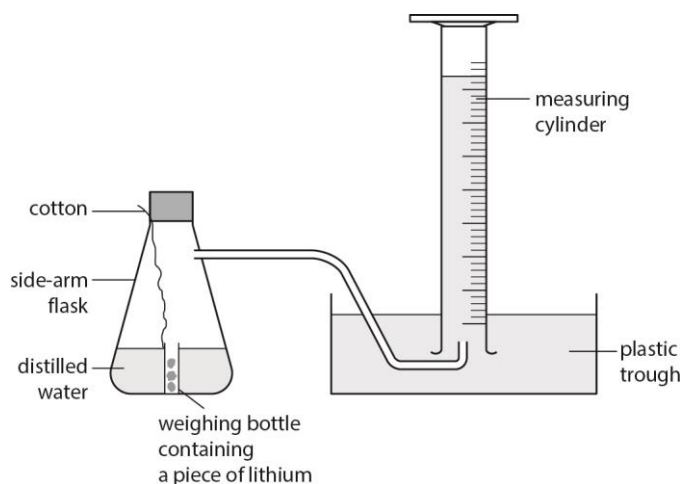
final answer:  $A_r$  of Li =  $7.7 \pm 0.8$

## Evaluation of experiment

5 % error =  $(7.7 - 6.94) / 6.94 \times 100\% = 11.0\%$

6 The systematic error reduces the volume of hydrogen measured, so the number of moles of lithium calculated will be smaller ( $n \propto V$ ), and the  $A_r$  calculated will be higher than it should be.

Modification: put a piece of lithium into a small weighing bottle and tie the bottle to a cotton string. When starting the reaction, shake the conical flask (with the bung on already) or pull the string, so the lithium piece can fall out of the weighing bottle and come into contact with the water.



7 Lithium is very reactive and is oxidised on its surface. This increases the mass of lithium measured, and the  $A_r$  calculated will be higher than it should be.

8 The percentage uncertainty in measuring the mass of lithium is the most significant. To reduce this error, a more precise balance could be used (one that measures to three decimal places), or a larger piece of lithium could be used.

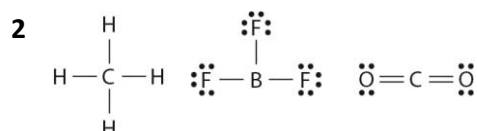
# Worksheet 6.1: The ionic model

- 1 An ion is an atom that has gained or lost an electron to have a positive or negative charge.
- 2 2+  
3+  
2-  
1-  
2-
- 3  $\text{MgBr}_2$   
 $\text{Ca}_3\text{N}_2$   
 $\text{FeI}_3$   
 $\text{K}_2\text{O}$   
 $\text{Al}(\text{NO}_3)_3$
- 4 A strong electrostatic force of attraction between oppositely charged ions.
- 5 Li forming  $\text{Li}^+$   
Cl forming  $\text{Cl}^-$   
Transfer of 1 electron from Li to Cl  
Ca forming  $\text{Ca}^{2+}$   
F forming  $\text{F}^-$   
Transfer of two electrons from Ca, one to each of the two Fs
- 6 3D lattice  
Alternating positive and negative charges  
Ions labelled correctly

# Worksheet 7.1: Shapes of molecules

## molecular models practical

1 models made



3 methane – tetrahedral

BF<sub>3</sub> – trigonal planar

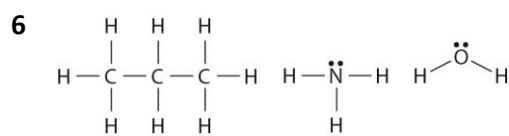
CO<sub>2</sub> – linear

4 methane – 109.5°, tetrahedral

boron trifluoride – 120°, trigonal planar

carbon dioxide – 180°, linear

5 models made



7 propane – tetrahedral

ammonia – trigonal pyramidal

water – bent or V shaped

8 methane – 109.5°, tetrahedral

ammonia – 107°, trigonal pyramidal

water – 104.5°, bent or V shaped

9 Lone pairs lie closer to the bonding pairs than the bonding pairs are to each other.

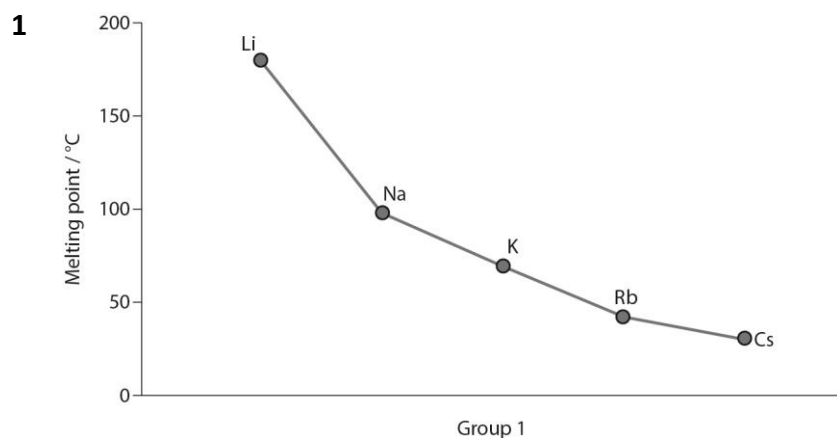
A general rule of thumb: if you are asked to predict a bond angle in a molecule, just take two or three degrees off the bond angle in the perfect shape (electron domain geometry) for each lone pair present on the central atom.

10 model made



12 Coordination bond is a type of covalent bond in which both electrons come from the same atom.

# Worksheet 8.1: The metallic model



- 2 All the elements in Group 1 have one electron in their outer shell and, therefore, form 1+ ions in the metallic lattice.

As we go down Group 1, the size of the ions increases. The attraction for the delocalised electrons is actually due to the nucleus of the positive ion. The positive ion gets larger as we go down the group; therefore, the nucleus is further from the delocalised electrons and the attraction becomes weaker.

Weaker attraction between the positive ions and the delocalized electrons (weaker metallic bonding) means that less energy is required to break apart the lattice as we go down Group 1 and the melting point decreases.

3

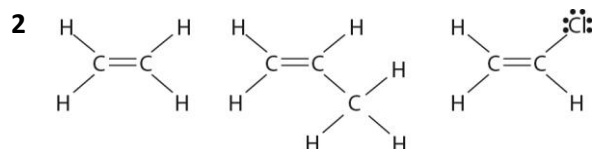
	Na	Mg	Al
Melting point (°C)	98	649	660

Aluminium has three outer-shell electrons and forms a 3+ ion, magnesium has two outer-shell electrons and forms a 2+ ion, but sodium, which has one outer-shell electron, forms a 1+ ion.

The electrostatic attraction between a 3+ ion and an electron is stronger than that between a 2+ ion and an electron, which is stronger than that between a 1+ ion and an electron.

# Worksheet 9.1: Polymers molecular models practical

1 models made



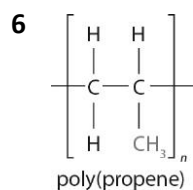
3 They all have a carbon–carbon double bond present.

4 models made

5 The double bond in the alkene is broken.

Single bonds between the molecules are formed

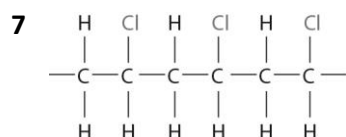
between both sides of the double bond and the adjacent molecules.



Correct structure

Continuation bonds

Square brackets and  $n$  in bottom-right corner.



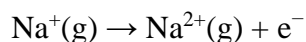
# Worksheet 10.1: The trends in the properties of elements down a group and across a period

- 1
  - a increases
  - b decreases
  - c decreases
  - d increases
- 2
  - a endothermic
  - b endothermic
  - c endothermic
  - d exothermic
  - e exothermic
- 3
  - a Na. From Na to Rb, there is an increase in the nuclear charge. However, shielding by the inner-shell electrons also increases due to the presence of more shells. Therefore, there is less electrostatic attraction between the nucleus and the outer-shell electron, and the atomic radius increases down the group.
  - b  $F^-$ . From  $F^-$  to  $Br^-$ , there is an increase in the nuclear charge. However, shielding by the inner-shell electrons also increases due to the presence of more shells. Therefore, there is less electrostatic attraction between the nucleus and the outer-shell electrons, and the ionic radius increases down the group.
  - c  $Na^+$ . From  $F^-$  to  $Na^+$ , the number of electrons stays the same / the species are isoelectronic. There is an increase in the nuclear charge with no change in shielding, so the electrostatic attraction between the nucleus and the outer-shell electron increases and the ionic radius decreases.
  - d  $Cl^-$ . From  $P^{3-}$  to  $Cl^-$ , the number of the electrons stays the same / the species are isoelectronic. There is an increase in the nuclear charge with no change in shielding, so the electrostatic attraction between the nucleus and the outer-shell electron increases and the ionic radius decreases.
  - e V. From Sc to V, the nuclear charge increases. There is an increasing number of electrons, but the additional electrons are added to an inner shell (3d). The electrostatic attraction between the nucleus and the outer-shell electron increases and the atomic radius decreases.
- 4 +5, +3, +5 and +4.



5 a  $1s^2 2s^2 2p^6 3s^1$

b The energy required to remove one mole of electrons from one mole of gaseous atoms under standard conditions.

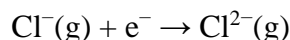


c The first electron in Na is removed from the 3s sub-shell and the second one is from 2p. The second electron is much closer to the nucleus and less shielded than the first, so it has a much stronger electrostatic attraction to the nucleus and requires much more energy to remove.

d Both electrons are removed from the 2p sub-shell. After removing the second electron, there are fewer electrons remaining, so there is less electron–electron repulsion. The third electron to be removed is closer to the nucleus, so it experiences more electrostatic attraction to the nucleus and requires more energy to remove.

e From Na to Mg, there is an increase in the nuclear charge without a significant change in the shielding for the outer-shell electron(s). The atomic radius decreases from Na to Mg, so there is an increasing electrostatic attraction from the outer-shell electron to the nucleus, and it requires more energy to remove the outer-shell electrons in Mg.

6 a Enthalpy / energy change when one electron is added to each atom in one mole of gaseous atoms under standard conditions.



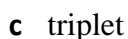
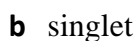
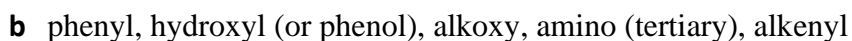
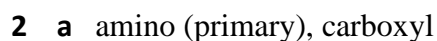
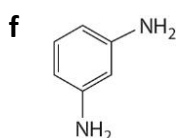
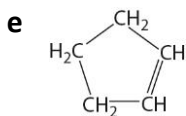
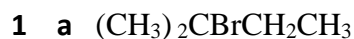
b The first electron affinity for Cl is negative, as the energy change is exothermic. Energy is released when an electron is brought from infinity to where it feels the attractive force of the nucleus in an atom.

The second electron affinity for Cl is positive, as the energy change is endothermic. Energy is required to overcome repulsion when adding another electron to an already negative  $\text{Cl}^-$  ion.

c From Cl to I, there is an increase in the number of shells of electrons, so the atomic radius increases. Although nuclear charge also increases, this is offset by the increasing shielding by inner-shell electrons. There is less electrostatic attraction between the nucleus and an incoming electron, so the electron affinity becomes less exothermic from Cl to I.

d F has a smaller atom than Cl, so it has more electron–electron repulsion between the incoming electron and the electrons already in the atom. F has a less exothermic electron affinity because some energy is required to overcome the extra repulsion.

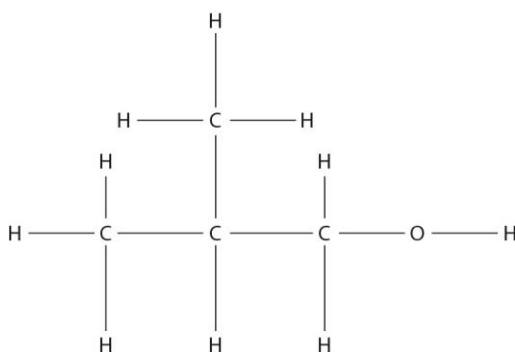
# Worksheet 11.1: Introduction to organic chemistry and analytical techniques



- 4 a This molecule is an alcohol, so has an -OH functional group.

	What to look for in the NMR spectrum	Information on the compound			
i	Number of different H environments (= number of peaks)	4			
ii	Types of H environments	$\delta = \sim 3.3$ ppm, R-O-CH <sub>2</sub> -	$\delta = \sim 2.1$ ppm, R-O-H as this molecule is an alcohol and there is one H in this environment	$\delta = \sim 1.7$ ppm, maybe -CHR <sub>2</sub>	$\delta = \sim 0.9$ ppm, -CH <sub>3</sub>
iii	Relative numbers of H in each environment	2	1	1	6
iv	Number of H atoms on adjacent C atoms	1, so the group is adjacent to a CH	0, so the group is adjacent to no hydrogen	Many, so the group is adjacent to multiple groups	1, so the group is adjacent to a CH

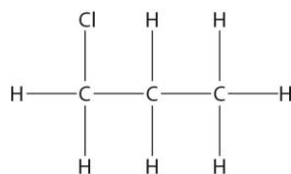
The molecule is



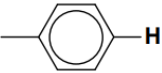
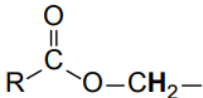
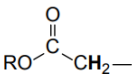
**b** This molecule is a chloroalkane.

	What to look for in the NMR spectrum	Information on the compound		
i	Number of different H environments	3		
ii	Types of H environments	$\delta = \sim 3.3\text{ppm}$ , is likely to be $-\text{CH}_2\text{-Cl}$	$\delta = \sim 1.7\text{ppm}$ , is likely to be $-\text{CH}_2\text{-R}$ next to other alkyl groups. The H's have higher chemical shift than in the data booklet due to the halogen present in the molecule.	$\delta = \sim 0.9\text{ppm}$ , $-\text{CH}_3$
iii	Relative numbers of H in each environment	2	2	3
iv	Number of H atoms on adjacent C atoms	2, so the group is adjacent to a $\text{CH}_2$	Many, so the group is adjacent to multiple groups	2, so the group is adjacent to a $\text{CH}_2$

The molecule is

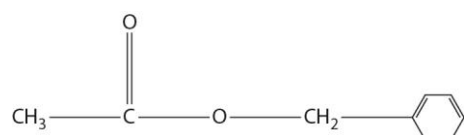


**c** This molecule is an ester

	What to look for in the NMR spectrum	Information on the compound		
i	Number of different H environments	3		
ii	Types of H environments	$\delta = \sim 7.3\text{ppm}$ confirming the presence of a benzene ring, 	$\delta = \sim 5.1\text{ppm}$ ,  this molecule is an ester so the H is likely to be next to the O in the $-\text{OCO}-$ group (data booklet value is 3.7-4.8ppm). The chemical shift might be increased due to the benzene group adjacent. It also fits with the information below that the adjacent atom has no H's attached.	$\delta = \sim 2.1\text{ppm}$ , 

	What to look for in the NMR spectrum	Information on the compound		
iii	Relative numbers of H in each environment	5, indicating the presence of a benzene ring	2	3
iv	Number of H atoms on adjacent C atoms	0	0	0

The molecule is



# Worksheet 12.1: Enthalpy change zinc + copper sulfate practical

## Analysis of results

- 1 From your own data
- 2 From your own data
- 3 From your own data
- 4 From your own data
- 5 From your own data
- 6 From your own data
- 7 From your own data

## Evaluation of experiment

- 8 This will work out the temperature change if the reaction happened instantaneously and will remove the heat loss to the surroundings error
- 9 Specific heat capacity is 4.18  
Mass of solution is the only substance heating up

# Worksheet 12.2: Burning alcohol practical

- 1** Volume of water  
Mass of alcohol at the start  
Mass of alcohol at the end  
Temperature of water at the start  
Highest temperature reached
- 2** The alcohol is pure  
The water is pure, so the specific heat capacity of water is 4.18
- 3** Volume of water measured  
Mass of alcohol measured (at start and end)  
Temperature at start and end  
(% uncertainty could be calculated for each of these)
- 4** Heat loss to the surroundings  
Evaporation of water  
The copper can is heated up  
Flame distance from can  
Draught / wind blowing on the flame  
Anything else that is reasonable

# Worksheet 13.1: Decomposition of calcium carbonate

## Analysis of results

- 1 From your own data
- 2 From your own data
- 3 From your own data
- 4 From your own data
- 5 From your own data
- 6 From your own data
- 7 From your own data
- 8 From your own data

## Evaluation of results

- 9 From your own data
- 10 Repeat the experiment to reduce the random errors.
- 11 Heat loss to the surroundings – insulate the reaction

Transference of chemicals to the reaction vessel – weigh out the solid in the reaction vessel

Reaction doesn't happen instantaneously – stir the reaction

Any other reasonable answer



# Worksheet 14.1: Energy from fuels

1	Advantages	Disadvantages
	<p><b>Coal</b></p> <p>Supplies should last hundreds of years. Distributed throughout the world.</p> <p>Can be converted into synthetic gaseous and liquid fuels.</p> <p><b>Oil</b></p> <p>Easily transported in pipelines or by tankers. Convenient fuel for transport – can be easily stored and used in vehicles. Source of variety of chemicals for the petrochemical industry.</p> <p><b>Natural gas</b></p> <p>A clean fuel – undergoes more complete combustion. Produces very few particulates / soot (C) or gases that contribute to acid rain when it burns. Easily transported in pipelines and tankers. Can be transported easily into homes through pipelines for heating and cooking. Releases a higher quantity of energy per kg than coal or oil. Produces less CO<sub>2</sub> per kJ of energy released than coal or oil.</p>	<p><b>Coal</b></p> <p>Not as easily transported as oil or gas. Mining is a dirty (slag heaps) and dangerous process. Dirty fuel – lots of incomplete combustion. Pollutants include particulates (soot) and sulfur dioxide (acid rain).</p> <p><b>Oil</b></p> <p>Very limited lifespan – supplies could run out in decades. Can produce sulfur dioxide (acid rain) when burned. Environmental problems associated with extraction and transportation in tankers. Only a few countries have reserves.</p> <p><b>Natural gas</b></p> <p>Limited lifespan – may be less than 100 years. Only certain countries have reserves. Methane is a powerful greenhouse gas and leaks during production and transportation of natural gas contribute to climate change. These leaks could offset any advantages due to it producing less CO<sub>2</sub> per kJ or kg. Risk of explosions due to leaks. More difficult to store than coal and oil because it is a gas – must be stored under pressure or cooled to liquefy it.</p>

## 2 Ethanol

The main producers of ethanol as a fuel are Brazil and the USA.

Made from sugar cane or corn – lots of land available to grow the crops.

Relatively cheap to produce

Ethanol can be mixed with gasoline for use as a fuel in cars.

3

Ethanol	Petrol
<b>Advantages:</b> Biofuels are renewable. Biofuels can be produced locally and reduce reliance on expensive oil imports from other countries. Biofuels can be produced from waste materials. Biofuels are biodegradable, and so, the potential environmental impact of spillages of biofuels is considerably lower than that of a spillage of crude oil.	<b>Advantages:</b> Cheaper than biofuels currently. Current infrastructure is designed for petrol (car engines work well and don't get damaged; transportation of petrol around the world is easy to do). In countries with crude oil, it is readily available. More energy efficient than biofuels.
<b>Disadvantages:</b> Growing biofuel crops requires large areas of land, which could be used for growing crops for food. Need the right climate to grow biofuel crops. Biofuels produce carbon dioxide when they are burnt. Can harm car engines.	<b>Disadvantages:</b> Fuels from petroleum are non-renewable. Spillage of crude oil can create massive environmental impacts. Made from crude oil, which is only available in certain countries around the world and can be expensive to export.

4 Student discussion

# Worksheet 15.1: Entropy and spontaneity

1

Reaction	Increase or decrease in entropy?	Reason
ice → water	Increase	Increase in the number of ways the energy can be distributed in water compared with ice
$\text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g}) \rightarrow \text{C}_2\text{H}_6(\text{g})$	Decrease	Fewer moles of gas on right-hand side (RHS)
$2\text{C}_2\text{H}_6(\text{g}) + 7\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l})$	Decrease	Fewer moles of gas on RHS
$\text{N}_2\text{O}_4(\text{g}) \rightarrow 2\text{NO}_2(\text{g})$	Increase	More moles of gas on RHS
$\text{NH}_3(\text{g}) + \text{HCl}(\text{g}) \rightarrow \text{NH}_4\text{Cl}(\text{s})$	Decrease	Fewer moles of gas on RHS
$2\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2\text{CO}(\text{g})$	Increase	More moles of gas on RHS

2  $\Delta S = (2 \times 192) - [192 + (3 \times 131)]$

$$\Delta S = -201 \text{ J K}^{-1} \text{ mol}^{-1}$$

3  $\Delta S = 230 - (201 + 131) = -102 \text{ J K}^{-1} \text{ mol}^{-1}$

$\Delta S$  is negative

Therefore there is a decrease in entropy, a decrease in the number of ways energy can be distributed

Fewer moles of gas on RHS

# Worksheet 16.1 How much? The amount of chemical change

## Analysis of results

- 1 From your own data
- 2 From your own data
- 3 From your own data
- 4 From your own data
- 5 From your own data
- 6 From your own data

## Evaluation of experiment

- 7 Some of the magnesium oxide is lost when it is heated (white smoke may have been seen when the lid was lifted off the crucible).

Not all the magnesium reacted.

Any other acceptable answers

- 8 Keep the lid on for longer; only let a little bit of air in each time.

Do the experiment for longer to ensure that the magnesium had reacted completely.

Weigh the crucible and then return and heat it, repeat this until the mass remains the same.

# Worksheet 17.1: Sodium thiosulfate and hydrochloric acid changing temperature practical

## Analysis of results

- 1 From your own data
- 2 From your own data
- 3 From your own data
- 4 From your own data
- 5 From your own data
- 6 From your own data

## Evaluation of experiment

- 7 Less energy would be given to the particles; therefore, fewer particles have energy greater than the activation energy, so there would be less frequent successful collisions and the rate of reaction would be slower.
- 8 Timing when the cross disappears
  - Stirring
  - Transference of solutions into the conical flask
  - Stock solutions not being exactly that concentration
  - Any other acceptable systematic error
- 9 Use a light sensor

# Worksheet 18.1 Equilibrium and Le Chatelier's principle

## 1 High pressure

Increasing pressure favours the side with the fewest moles of gas, which will shift the position of equilibrium to the right-hand side, increasing the yield of ammonia.

## Low temperature

Decreasing the temperature favours the endothermic side, which will shift the position of equilibrium to the right-hand side, increasing the yield of ammonia.

(accept reverse arguments)

## 2 High temperature increases the rate of reaction to get to equilibrium faster.

A higher yield of ammonia can be obtained in a shorter period of time.

## 3 A catalyst has no effect on the position of equilibrium.

## 4 A catalyst speeds up the rate of reaction, so it reaches equilibrium more quickly; therefore, more ammonia can be produced in a shorter period of time.

# Worksheet 19.1: Practical on acid–base titration using a pH meter, with 0.1 mol dm<sup>-3</sup> aqueous solutions of NaOH, HCl, NH<sub>3</sub> and CH<sub>3</sub>COOH

## Analysis of results

- 1 Sample data for adding 0.1 mol dm<sup>-3</sup> NaOH into 25 cm<sup>3</sup> of 0.1 mol dm<sup>-3</sup> of CH<sub>3</sub>COOH  
volume of CH<sub>3</sub>COOH = 25.00 ± 0.06 cm<sup>3</sup> (0.06 is the absolute uncertainty on a 25cm<sup>3</sup> glass pipette.)  
concentration of CH<sub>3</sub>COOH = 0.1 mol dm<sup>-3</sup>  
concentration of NaOH = 0.1 mol dm<sup>-3</sup>

Volume of NaOH added (± 0.05 cm <sup>3</sup> )	pH (± 0.01)
0.00	3.37
0.50	3.68
1.00	3.56
1.50	3.82
2.00	3.95
2.50	4.09
3.00	4.27
3.50	4.33
4.00	4.44
4.50	4.49
5.00	4.55
5.50	4.51
6.00	4.56
6.50	4.63
7.00	4.71
7.50	4.77
8.00	4.81
8.50	4.77

Volume of NaOH added ( $\pm 0.05 \text{ cm}^3$ )	pH ( $\pm 0.01$ )
9.00	4.85
9.50	4.92
10.00	4.94
10.50	5.01
11.00	5.05
11.50	5.08
12.00	5.18
12.50	5.16
13.00	5.22
13.50	5.25
14.00	5.31
14.50	5.33
15.00	5.38
15.50	5.45
16.00	5.45
16.50	5.46
17.00	5.53
17.50	5.56
18.00	5.61
18.50	5.68
19.00	5.80
19.50	5.92
20.00	5.99
20.50	6.09
21.00	6.19
21.50	6.43
22.00	6.76
22.50	7.82
23.00	10.73



Volume of NaOH added ( $\pm 0.05 \text{ cm}^3$ )	pH ( $\pm 0.01$ )
23.50	11.23
24.00	11.58
24.50	11.68
25.00	11.82
25.50	11.90
26.00	11.94
26.50	11.98
27.00	12.01
27.50	12.13
28.00	12.17
28.50	12.18
29.00	12.18
29.50	12.22
30.00	12.24
30.50	12.24
31.00	12.27
31.50	12.30
32.00	12.31
32.50	12.31
33.00	12.33
33.50	12.36
34.00	12.37
34.50	12.33
35.00	12.36
35.50	12.38
36.00	12.39
36.50	12.40
37.00	12.41
37.50	12.41

Volume of NaOH added ( $\pm 0.05 \text{ cm}^3$ )	pH ( $\pm 0.01$ )
38.00	12.41
38.50	12.41
39.00	12.42
39.50	12.44
40.00	12.45
40.50	12.46
41.00	12.46
41.50	12.46
42.00	12.47
42.50	12.48
43.00	12.49
43.50	12.49
44.00	12.49
44.50	12.49
45.00	12.49
45.50	12.49
46.00	12.49
46.50	12.54
47.00	12.58
47.50	12.59
48.00	12.59
48.50	12.60
49.00	12.60
49.50	12.61
50.00	12.62

- 2  $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$   
 $\text{HCl} + \text{NH}_3 \rightarrow \text{NH}_4\text{Cl}$   
 $\text{CH}_3\text{COOH} + \text{NaOH} \rightarrow \text{CH}_3\text{COONa} + \text{H}_2\text{O}$   
 $\text{CH}_3\text{COOH} + \text{NH}_3 \rightarrow \text{CH}_3\text{COONH}_4$
- 3 The curves should be similar to Figures **19.10**, **19.14**, **19.17** and **19.20** in the Coursebook.

- 4 The equivalence point is the point of inflection on the titration curve, where the pH change is the fastest.
- 5 pH of HCl = 1  
pH of CH<sub>3</sub>COOH = 2.88

## Evaluation of experiment

- 6 So the pH values obtained are accurate and do not carry systematic errors.
- 7 Wash a 25 cm<sup>3</sup> pipette with the provided HCl, and then fill it with the same acid using a pipette filler. The bottom of the meniscus of the acid should touch the mark on the pipette, at eye level.
- 8 Using the sample data from Question 1:  
 $(3.37 - 2.88) / 2.88 \times 100\% = 17.0\%$
- 9 HCl and NaOH: pH = 7

HCl is a strong acid and NaOH is a strong alkali. Both fully dissociate in aqueous solutions. At equivalence point, there are equal concentrations of H<sup>+</sup> and OH<sup>-</sup> and pH = 7.

HCl and NH<sub>3</sub>: pH < 7

HCl is a strong acid and NH<sub>3</sub> is a weak alkali. HCl fully dissociates in an aqueous solution. NH<sub>4</sub><sup>+</sup> formed in the salt is a relatively strong acid (as it is derived from a weak alkali) and dissociates to form H<sup>+</sup>:  $\text{NH}_4^+ \rightleftharpoons \text{NH}_3 + \text{H}^+$

At equivalence point, there is a higher concentration of H<sup>+</sup> than OH<sup>-</sup> and pH < 7.

CH<sub>3</sub>COOH and NaOH: pH > 7

CH<sub>3</sub>COOH is a weak acid and NaOH is a strong alkali. NaOH fully dissociates in an aqueous solution. CH<sub>3</sub>COO<sup>-</sup> formed in the salt is a relatively strong alkali (as it is derived from a weak acid) and can associate with water to form OH<sup>-</sup>:  $\text{CH}_3\text{COO}^- + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COOH} + \text{OH}^-$ .

At equivalence point, there is a higher concentration of OH<sup>-</sup> than H<sup>+</sup> and pH > 7.

CH<sub>3</sub>COOH and NH<sub>3</sub>: pH ~7

The pH is very close to 7 as the pK<sub>a</sub> for CH<sub>3</sub>COOH is very similar to the pK<sub>b</sub> for NH<sub>3</sub>. In the data booklet, the pK<sub>a</sub> of CH<sub>3</sub>COOH is 4.76 and the pK<sub>b</sub> of NH<sub>3</sub> is 4.75. This means CH<sub>3</sub>COO<sup>-</sup> is a slightly stronger base than NH<sub>4</sub><sup>+</sup> as an acid and the pH at equivalence point should be slightly higher than 7.

- 10  $\text{HIn} \rightleftharpoons \text{H}^+ + \text{In}^-$

HIn and In<sup>-</sup> have different colours.

When an acid is added into the indicator, the concentration of H<sup>+</sup> increases and the position of equilibrium shifts left. The indicator shows the colour of HIn.

When an alkali is added into the indicator, the concentration of H<sup>+</sup> decreases and the position of equilibrium shifts right. The indicator shows the colour of In<sup>-</sup>.

- 11** HCl and NaOH: any of the indicators listed in the data booklet should be fine.

HCl and  $\text{NH}_3$ : methyl orange and bromophenol blue

$\text{CH}_3\text{COOH}$  and NaOH: phenolphthalein

Reason: the pH range of the indicator should coincide with the steepest part of the titration curve.

$\text{CH}_3\text{COOH}$  and  $\text{NH}_3$ : no suitable indicator as the titration curve does not have a steep part.

- 12** The pH range of an indicator is the range over which an indicator changes colour. The equivalence point of a titration curve is when equal numbers of moles of acid and base have been added and it is the point of inflection on the titration curve. The range of an indicator should include the equivalence point of a titration curve so that the indicator changes colour when the equivalence point is reached. However, they do not have to be the same.

# Worksheet 19.2: Practical on making buffers and testing their buffering capacities

## Analysis of results

- 1 Sample data: Buffer 1: 25 cm<sup>3</sup> CH<sub>3</sub>COOH with 25 cm<sup>3</sup> CH<sub>3</sub>COONa  
 volume of CH<sub>3</sub>COOH = 25.00 ± 0.06 cm<sup>3</sup> (0.06 is the absolute uncertainty on a 25cm<sup>3</sup> glass pipette.)  
 concentration of CH<sub>3</sub>COOH = 0.5 mol dm<sup>-3</sup>  
 volume of CH<sub>3</sub>COONa = 25.00 ± 0.06 cm<sup>3</sup>  
 concentration of CH<sub>3</sub>COONa = 0.5 mol dm<sup>-3</sup>  
 concentration of NaOH = 0.5 mol dm<sup>-3</sup>

Volume of NaOH added (± 0.05 cm <sup>3</sup> )	pH (± 0.01)
0.00	4.42
0.50	4.43
1.00	4.44
1.50	4.47
2.00	4.48
2.50	4.49
3.00	4.52
3.50	4.54
4.00	4.56
4.50	4.59
5.00	4.60
5.50	4.62
6.00	4.64
6.50	4.66
7.00	4.69
7.50	4.70
8.00	4.71
8.50	4.74
9.00	4.75
9.50	4.78

Volume of NaOH added ( $\pm 0.05 \text{ cm}^3$ )	pH ( $\pm 0.01$ )
10.00	4.79
10.50	4.81
11.00	4.84
11.50	4.86
12.00	4.89

Buffer 2:  $15 \text{ cm}^3 \text{ CH}_3\text{COOH}$  with  $35 \text{ cm}^3 \text{ CH}_3\text{COONa}$

volume of  $\text{CH}_3\text{COOH} = 15.00 \pm 0.06 \text{ cm}^3$

concentration of  $\text{CH}_3\text{COOH} = 0.5 \text{ mol dm}^{-3}$

volume of  $\text{CH}_3\text{COONa} = 35.00 \pm 0.06 \text{ cm}^3$

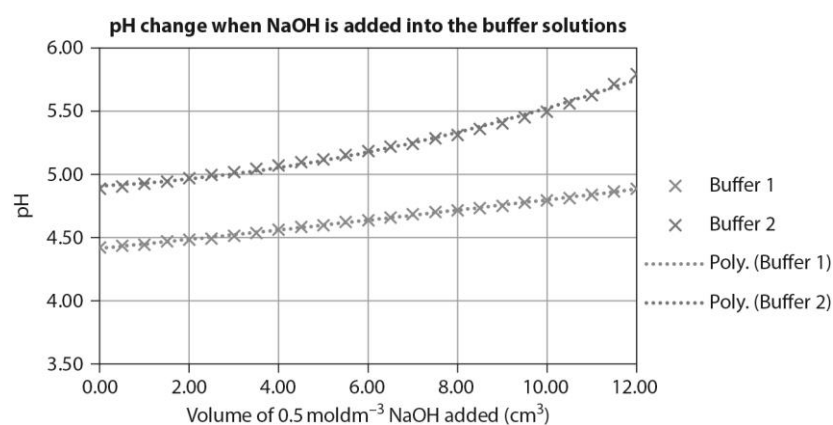
concentration of  $\text{CH}_3\text{COONa} = 0.5 \text{ mol dm}^{-3}$

concentration of NaOH =  $0.5 \text{ mol dm}^{-3}$

Volume of NaOH added ( $\pm 0.05 \text{ cm}^3$ )	pH ( $\pm 0.01$ )
0.00	4.89
0.50	4.91
1.00	4.92
1.50	4.94
2.00	4.97
2.50	5.00
3.00	5.02
3.50	5.04
4.00	5.07
4.50	5.10
5.00	5.12
5.50	5.15
6.00	5.18
6.50	5.22
7.00	5.24
7.50	5.28
8.00	5.31
8.50	5.36

Volume of NaOH added ( $\pm 0.05 \text{ cm}^3$ )	pH ( $\pm 0.01$ )
9.00	5.40
9.50	5.45
10.00	5.50
10.50	5.56
11.00	5.63
11.50	5.71
12.00	5.79

2 From the sample data for Question 1:



## Evaluation of experiment

3  $25 \text{ cm}^3 \text{ CH}_3\text{COOH}$  with  $25 \text{ cm}^3 \text{ CH}_3\text{COONa}$

4 The following equilibrium exists in the buffer solution:  
 $\text{CH}_3\text{COOH} \rightleftharpoons \text{H}^+ + \text{CH}_3\text{COO}^-$

When an acid is added, the conjugate base,  $\text{CH}_3\text{COO}^-$ , will react with the added  $\text{H}^+$  and shift the position of equilibrium to the left to reduce the  $\text{H}^+$  concentration. When an alkali is added, the conjugate acid,  $\text{CH}_3\text{COOH}$ , will react with  $\text{OH}^-$  and shift the position of equilibrium to the right. This reduces the  $\text{OH}^-$  concentration. Therefore, pH stays more or less the same in an effective buffer. The changes in the concentrations of  $\text{CH}_3\text{COOH}$  and  $\text{CH}_3\text{COO}^-$  are small in comparison to their original concentrations.

5 Expected values:

$45 \text{ cm}^3 \text{ CH}_3\text{COOH}$  with  $5 \text{ cm}^3 \text{ CH}_3\text{COONa}$  pH = 3.81

$35 \text{ cm}^3 \text{ CH}_3\text{COOH}$  with  $15 \text{ cm}^3 \text{ CH}_3\text{COONa}$  pH = 4.39

$25 \text{ cm}^3 \text{ CH}_3\text{COOH}$  with  $25 \text{ cm}^3 \text{ CH}_3\text{COONa}$  pH = 4.76

percentage error from sample data =  $(4.76 - 4.42) / 4.76 \times 100\% = 7.14\%$

$15 \text{ cm}^3 \text{ CH}_3\text{COOH}$  with  $35 \text{ cm}^3 \text{ CH}_3\text{COONa}$  pH = 5.13

percentage error from sample data =  $(5.13 - 4.89) / 5.13 \times 100\% = 4.68\%$

$5 \text{ cm}^3 \text{ CH}_3\text{COOH}$  with  $45 \text{ cm}^3 \text{ CH}_3\text{COONa}$  pH = 5.71

# Worksheet 20.1: Practical to determine the iron(II) content in iron tablets

## Analysis of results

### 1 Part 1

volume of  $\text{H}_2\text{SO}_4 = 50 \pm 1 \text{ cm}^3$

concentration of  $\text{H}_2\text{SO}_4 = 1 \text{ mol dm}^{-3}$

number of iron tablets = 5

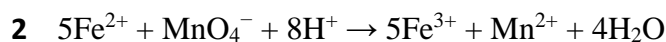
### Part 2

concentration of  $\text{KMnO}_4 = 0.02 \text{ mol dm}^{-3}$

volume of  $\text{Fe}^{2+}$  solution =  $100.00 \pm 0.03 \text{ cm}^3$

volume of  $\text{Fe}^{2+}$  solution titrated =  $25.00 \pm 0.06 \text{ cm}^3$

	Trial	Titration 1	Titration 2	Titration 3
Initial burette reading ( $\pm 0.05 \text{ cm}^3$ )	0.00	13.65	27.15	0.00
Final burette reading ( $\pm 0.05 \text{ cm}^3$ )	13.65	27.15	40.75	13.50



### 3

	Trial	Titration 1	Titration 2	Titration 3
Titre ( $\pm 0.1 \text{ cm}^3$ )	13.7	13.5	13.6	13.5

average titre =  $(13.5 + 13.6 + 13.5) / 3 = 13.5 \text{ cm}^3$

number of moles of  $\text{MnO}_4^- = 0.00027 \text{ mol}$

number of moles of  $\text{Fe}^{2+}$  in  $25 \text{ cm}^3$  of solution =  $0.00135 \text{ mol}$

number of moles of  $\text{Fe}^{2+}$  in  $100 \text{ cm}^3$  of solution =  $0.0054 \text{ mol}$

mass of  $\text{Fe}^{2+} = 0.3016 \text{ g}$

mass of Fe per tablet =  $60.32 \text{ mg}$

4 percentage uncertainty in the average titre =  $0.1 / 13.5 \times 100\% = 0.741\%$

percentage uncertainty in the mass of  $\text{Fe}^{2+}$  in one tablet =  $(0.1 / 13.5 + 0.06 / 25.00 + 0.03 / 100.00) \times 100\% = 1.01\%$

absolute uncertainty in the mass of  $\text{Fe}^{2+}$  in one tablet =  $1.01\% \times 60.32 = 0.6 \text{ mg}$



## Evaluation of experiment

- 5 Manufacturer's information: mass of  $\text{Fe}^{2+}$  in one tablet = 66 mg  
percentage error =  $(66-60.3)/66 \times 100\% = 8.64\%$
- 6 Absolute uncertainty in the burette reading of the  $\text{KMnO}_4$  volume used.  
Absolute uncertainty in the pipette reading of the volume of  $\text{Fe}^{2+}$  solution.  
Lack of repeats.
- 7  $\text{Mn}^{2+}$  is very pale pink and appears almost colourless when it forms in the conical flask. As a result, the reaction is complete when a permanent pink colour appears, indicating a slight excess of  $\text{MnO}_4^-$ .  
The titration is self-indicating and does not require an indicator.
- 8 The  $\text{Cl}^-$  in  $\text{HCl}$  can be oxidised by  $\text{MnO}_4^-$ , and  $\text{HNO}_3$  is a strong oxidising agent that can react with  $\text{Fe}^{2+}$ .

# Worksheet 20.2: Practical on setting up voltaic cells and measuring voltages

## Analysis of results

1 Examples of observations for the  $\text{Mg}|\text{MgSO}_4||\text{CuSO}_4|\text{Cu}$  cell: the magnesium electrode is dull on its surface at the beginning of the experiment; the magnesium electrode shrinks; pink-brownish copper forms on the copper electrode; the blue colour of  $\text{CuSO}_4$  becomes paler.

2 Sample data:

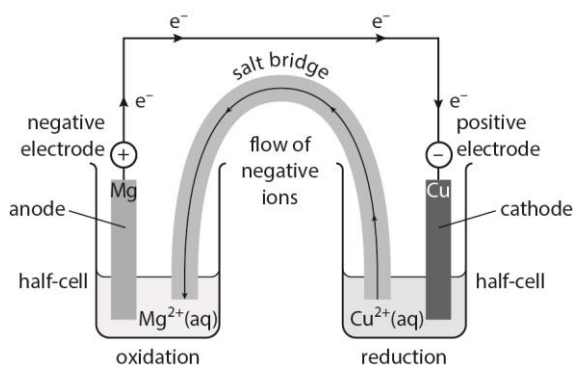
concentration of  $\text{MgSO}_4$ ,  $\text{ZnSO}_4$ ,  $\text{FeSO}_4$  and  $\text{CuSO}_4 = 1 \text{ mol dm}^{-3}$

volume of  $\text{MgSO}_4$ ,  $\text{ZnSO}_4$ ,  $\text{FeSO}_4$  and  $\text{CuSO}_4 = 50.0 \pm 0.5 \text{ cm}^3$

Cell	Cell potential $\pm 0.01 \text{ V}$
$\text{Mg} \text{MgSO}_4  \text{CuSO}_4 \text{Cu}$	1.84
$\text{Zn} \text{ZnSO}_4  \text{CuSO}_4 \text{Cu}$	1.09
$\text{Fe} \text{FeSO}_4  \text{CuSO}_4 \text{Cu}$	0.56
$\text{Mg} \text{MgSO}_4  \text{ZnSO}_4 \text{Zn}$	0.80
$\text{Mg} \text{MgSO}_4  \text{FeSO}_4 \text{Fe}$	1.33
$\text{Zn} \text{ZnSO}_4  \text{FeSO}_4 \text{Fe}$	0.50

3 For the  $\text{Mg}|\text{MgSO}_4||\text{CuSO}_4|\text{Cu}$  cell,  $\text{Mg} + \text{CuSO}_4 \rightarrow \text{MgSO}_4 + \text{Cu}$ ,  $\text{Mg} + \text{Cu}^{2+} \rightarrow \text{Cu} + \text{Mg}^{2+}$

4



5 The salt bridge completes the circuit, and it allows ions to flow into / out of the half-cells to balance out charges.

6 Reducing agents:  $\text{Mg} > \text{Zn} > \text{Fe} > \text{Cu}$

Oxidising agents:  $\text{Cu}^{2+} > \text{Fe}^{2+} > \text{Zn}^{2+} > \text{Mg}^{2+}$

## Evaluation of experiment

7  $\text{Mg}|\text{MgSO}_4||\text{ZnSO}_4|\text{Zn}$  cell  $E = 1.61 \text{ V}$

$\text{Mg}|\text{MgSO}_4||\text{FeSO}_4|\text{Fe}$  cell  $E = 1.92 \text{ V}$

$\text{Mg}|\text{MgSO}_4||\text{CuSO}_4|\text{Cu}$  cell  $E = 2.71 \text{ V}$

$\text{Zn}|\text{ZnSO}_4||\text{FeSO}_4|\text{Fe}$  cell  $E = 0.31 \text{ V}$

$\text{Zn}|\text{ZnSO}_4||\text{CuSO}_4|\text{Cu}$  cell  $E = 1.10 \text{ V}$

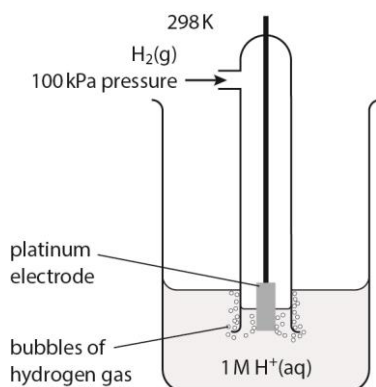
$\text{Fe}|\text{FeSO}_4||\text{CuSO}_4|\text{Cu}$  cell  $E = 0.79 \text{ V}$

8 From the sample data in Question 2:

Cell	Measured cell potential $\pm 0.01 \text{ V}$	Percentage error
$\text{Mg} \text{MgSO}_4  \text{CuSO}_4 \text{Cu}$	1.84	32.1%
$\text{Zn} \text{ZnSO}_4  \text{CuSO}_4 \text{Cu}$	1.09	0.909%
$\text{Fe} \text{FeSO}_4  \text{CuSO}_4 \text{Cu}$	0.56	29.1%
$\text{Mg} \text{MgSO}_4  \text{ZnSO}_4 \text{Zn}$	0.80	50.3%
$\text{Mg} \text{MgSO}_4  \text{FeSO}_4 \text{Fe}$	1.33	30.7%
$\text{Zn} \text{ZnSO}_4  \text{FeSO}_4 \text{Fe}$	0.50	61.3%

9 A potentiometer is used to minimise the current in the circuit and, therefore, as little reaction happens as possible. If a (forward) reaction occurs, the ion concentrations change in the half-cells and the cell potential measured will decrease.

10 Hydrogen gas at 100 kPa is bubbled into a solution of  $1 \text{ mol dm}^{-3}$  of  $\text{H}^+$  ions. The platinum electrode is inert and provides a surface for  $\text{H}_2$  gas to be in contact with the  $\text{H}^+$  solution.



- 11** Some metals are dull on their surfaces – if the metals are the anodes, the cell potential measured will be lower than it should be.

The salt solutions might not be exactly  $1 \text{ mol dm}^{-3}$ .

The voltmeter does not have very high resistance and a current is drawn. This reduces the cell potential measured as the forward reaction occurs.

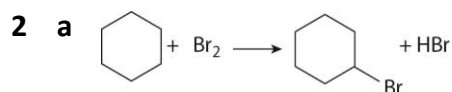
- 12** Clean the surface of the metals with sandpaper or use fresh pieces of metals.

Make the solutions from solid salts using volumetric flasks.

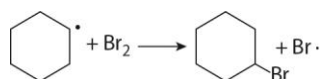
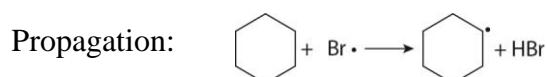
Replace the voltmeter with a higher resistance potentiometer.

# Worksheet 21.1: The formation of halogenoalkanes in radical reactions

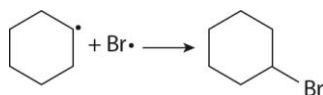
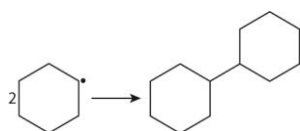
1 1,3-dibromo-3-chlorobutane; 1-chlorobutane; 3-ethyl-2-fluoropentane; 2-bromo-1-chloropropane



b Initiation:  $\text{Br}_2 \rightarrow 2\text{Br}\cdot$



Termination:  $2\text{Br}\cdot \rightarrow \text{Br}_2$

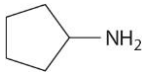
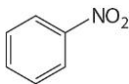


c A free radical is a chemical species containing an unpaired electron. Free radicals are very reactive.

Homolytic fission is the breaking of a covalent bond (made up of two electrons) so that one electron goes back to each atom that made up the original bond.

d 5

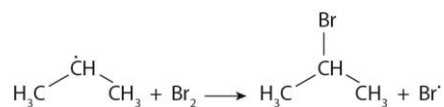
# Worksheet 22.1: Lewis acids and bases and their roles in organic reactions

- 1
  - a base:  $\text{NH}_3$ ; acid:  $\text{BCl}_3$
  - b acid:  $(\text{CH}_3)_3\text{CBr}$ ; base:  $\text{OH}^-$
  - c  $\text{H}_2\text{O}$  is both the acid and the base
  - d base:  $\text{H}_2\text{C}=\text{CH}_2$ ; acid:  $\text{H}_2\text{O}$
  - e base:  $\text{HNO}_3$ ; acid:  $\text{H}_2\text{SO}_4$
  - f acid:  $\text{Fe}^{3+}$ ; base:  $\text{CN}^-$
  - g acid:  $\text{AlCl}_3$ ; base:  $\text{Cl}_2$
- 2
  - a  $\text{CH}_3\text{CHBrCH}_3$  (electrophilic) addition
  - b  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$  (nucleophilic) substitution
  - c  $\text{CH}_3\text{COCH}_3$  oxidation
  - d  $(\text{CH}_3)_2\text{CCNCH}_2\text{CH}_3$  (nucleophilic) substitution
  - e  $\text{HOCH}_2\text{CH}_2\text{OH}$  reduction
  - f  (nucleophilic) substitution
  - g  (electrophilic) substitution or nitration
- 3
  - a
    - step 1:**  $\text{Br}_2$ , UV/sunlight
    - step 2:**  $\text{H}_2$ , nickel catalyst, heat
    - step 3:**  $\text{HBr}$
    - step 4:**  $\text{H}_2\text{O}$ , concentrated  $\text{H}_2\text{SO}_4$ , heat *or*  $\text{H}_2\text{O(g)}$ ,  $\text{H}_3\text{PO}_4$ ,  $300^\circ\text{C}$  and 60–70 atm
    - step 5:**  $\text{NaOH(aq)}$ , heat
    - step 6:**  $\text{CH}_3\text{COOH}$ , concentrated  $\text{H}_2\text{SO}_4$ , heat
    - step 7:** acidified potassium dichromate(VI) *or*  $\text{H}^+ / \text{Cr}_2\text{O}_7^{2-}$ , heat under reflux
  - b
    - step 8:** (nucleophilic) substitution
    - step 9:** condensation / nucleophilic addition–elimination
    - step 10:** addition polymerisation

**c step 1:**

initiation:  $\text{Br}_2 \rightarrow 2\text{Br}\cdot$

propagation:  $\text{H}_3\text{C}-\text{CH}_2-\text{CH}_3 + \text{Br}\cdot \rightarrow \text{H}_3\text{C}-\dot{\text{C}}\text{H}-\text{CH}_3 + \text{HBr}$



termination:  $2\text{Br}\cdot \rightarrow \text{Br}_2$

