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KEEP IT SIMPLE SCIENCE
Chemistry Module 8
Applying Chemical Ideas
WORKSHEETS

Worksheet 1   Qualitative Identification of Ions
Practice Problems

Student Name...

1.
Samples of a solution known to contain <u>one ionic compound</u> were tested as follows:
(each test began with a fresh sample)

	added	Result
a)	Cl^-	no reaction
b)	SO_4^{2-}	no reaction
c)	OH^-	blue precipitate
d)	acid	no reaction
e)	Fe^{3+}	no reaction
f)	Ba^{2+}	white precipitate

For each test a),b), etc. state the conclusion drawn. Finally, name the compound.

2.
In a similar series of tests to Q1, another solution was tested as follows:

	Added	Result
a)	sulfate ion	no reaction
b)	hydroxide ion	green precipitate, turned brown
c))	barium ion	no reaction
d)	silver ion	white precipitate, darkened.

For each test a),b), etc. state the conclusion drawn.

3.
In Q2, what additional test might be used after test (d) to confirm the anion identity?

4.
A solid ionic compound flares "brick-red" in a flame test and fizzes bubbles when acid is added.
What is it?

5.
An ionic solution forms a white precipitate when NaCl added. It also forms a white pptte with NaOH. In this case, the pptte re-dissolves if excess NaOH is added.
What is the cation? Explain.

6.
To identify the cation in a solution, NaCl was added without result. When K_2SO_4 was added to a fresh sample, a white pptte formed.
a) What are the possibilities?

b) What would you do next?

c) Give 2 possible outcomes and conclusion for each.

7.
An "unknown" solution produced a thick white pptte when Ba^{2+} ions were added.
When fresh samples were tested with Cl^- and (separately) SO_4^{2-} no reactions occurred.
Adding NaOH produced a faint white pptte.
Conclusion? Explain your reasoning.

8.
If a solution of sodium ethanoate (or "acetate") has some acid solution added, then is warmed, it smells of vinegar. Explain (including an equation)

Worksheet 2
Fill in the blanks

Background Knowledge

Student Name.......................................

Qualitative Analysis means to a)............................ a chemical species. To analyse quantitatively means to b)...

Some human activities release dangerous ions (or harmful amounts) into the environment. For example, phosphate ions can cause the process of c)............................. to occur in water environments. This involves excessive d)............... ....   Later, the dead, rotting vegetation e)............... .... from the water. The main sources of extra phosphate are f)............................ and ....

Lead ions can g)................................. in the body and cause h)....................... .... in children. Until recently, the main source of lead pollution was from the use of i)....................... ....

The simplest qualitative tests to identify ions is to use j)................................ reactions and k)................. tests. Of the syllabus cations, 3 give distinctive colours in a flame test: barium flares l)...................., calcium flares m)............... & copper flares n).............

AAS stands for o).. .... This technique is able to quantitatively measure extremely small concentrations of an element. Basically, it works by measuring the amount of p)............................ absorbed by atoms in a vaporised sample. Each element has its own unique absorption q)................................ The AAS equipment is able to select the r)............................. of light which correspond to the s)........................... spectrum of the element being analysed.

AAS has made it possible to study "t)....................." elements which could not be previously analysed easily. In a famous case, AAS analysis solved a major problem in a sheep-farming area by detecting a deficiency of u)................................. which was making the sheep sick. AAS also makes it possible to monitor pollutants such as v)..........................., which is dangerous even at low levels in the environment.

Worksheet 3   Gravimetric Analysis

Student Name.......................................

1.
A soil sample was analysed as follows:
Step 1: An evaporating dish was weighed.
          mass of basin = 42.85g
Step 2: Soil sample added and basin re-weighed:
          mass soil+basin = 54.27g
Step 3: Basin placed in oven at 80°C until mass was constant.   mass after drying = 52.66g
Step 4: Placed in oven at extremely high temperature. (this burns away all the organic (plant) matter, leaving only the minerals.)
Cooled, re-weighed.   final mass = 46.72g

a) Calculate the mass of:
i) the soil sample.

ii) the water in the sample.

iii) the organic matter in the sample.

iv) the minerals in the sample.

b) Calculate the percentage composition of the soil sample.

c) Which step in the analysis involved a chemical change?

d) Why was it important, in Step 3, for the dish to be left in the oven until the mass was constant?

2.
To measure the amount of chloride ion in a sample of sea water, an excess of silver ions (as silver nitrate solution) was added.

a) Write an equation for the reaction between silver and chloride ions.

b) From a 50.0g sample of seawater, the mass of dried precipitate collected was 3.42g.
Find % by mass of chloride ion in the sample.

3.
A lawn fertiliser was analysed gravimetrically by dissolving a sample in dilute hydrochloric acid, adding excess Ba^{2+} ion, then collecting the $BaSO_4$ precipitate, drying and weighing.
Sample mass = 4.46g
Mass of $BaSO_4$ collected = 3.27g

Calculate the % by mass of sulfate in the fertiliser.

Worksheet 4   Precip.Titration & Colorimetry

Student Name.......................................

1.
To find the lead content of a sample of galena, (lead ore, mostly lead sulfide) a 8.62g sample was crushed to powder, then dissolved in about 100mL dilute nitric acid. (This dissolves the lead as lead(II) nitrate.) After filtering out the insoluble impurities, the filtrate was made up to exactly 500mL.

A 25.0mL aliquot of this was titrated against a 0.140 $molL^{-1}$ solution of sodium iodide. The reaction forms insoluble lead(II) iodide. The end point was determined by monitoring the conductivity of the mixture.
Results

Vol. NaI soln (mL) added	0	10	20	30	40	50
Conductivity (arbitrary units)	7.3	4.8	2.4	2.9	5.3	5.8

a) Write an equation for the reaction involved.

b) Plot the results data on the grid at right then determine the end-point.

c) Calculate the concentration of Pb^{2+} in the 25mL aliquot and hence the % by mass of lead in the ore sample.

Graph: Electrical Conductivity (arbitrary units) vs Vol. NaI soln (mL)
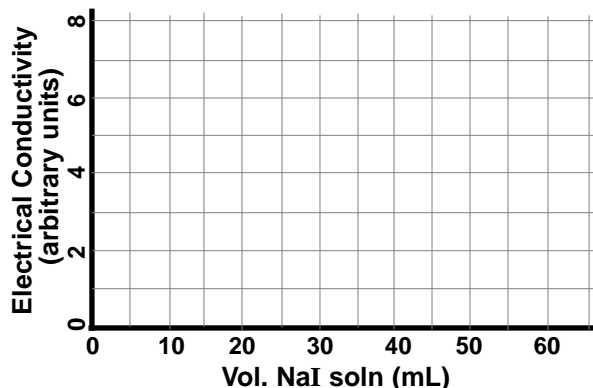
2.
The phosphate concentration of a polluted pond suffering eutrophication was determined by <u>colourimetry</u> as follows.

A standard solution of PO_4^{3-} with concentration of 5.00×10^{-3} $molL^{-1}$ was diluted (as shown) to form a series of known-strength solutions, to have their light absorbance measured, to prepare a calibration graph.
Dilution Scheme

Solution No.	1.	2.	3.	4.	5.	6.
mL of std.soln.	10.0	8.0	6.0	4.0	2.0	0
mL of pure water	0	2.0	4.0	6.0	8.0	10.0

Each solution was treated identically with reagents which form a blue-violet coloured complex ion by reaction with phosphate ions.

Each then had its % light absorbance measured in identical fashion by a colorimeter. (solution No.6 was used to set the colourimeter scale to zero.)
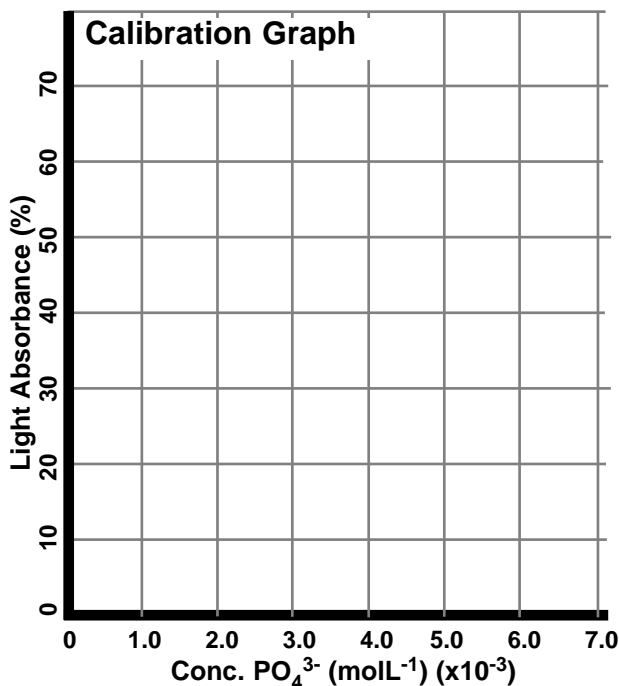
Results

Solution No.	1.	2.	3.	4.	5.	6.
% Absorbance	62	50	38	24	13	0

a) Calculate the concentration of each standard solution, then plot these results on the grid at right to construct the calibration graph.

b) A 5.00mL sample of pond water was made up to 100mL in a volumetric flask.
10.0 mL of this solution was treated identically to the standard solutions, then its absorbance was measured. The value returned was 31% absorbance.

Calculate the concentration of phosphate ion in the pond.

Calibration Graph
Graph: Light Absorbance (%) vs Conc. PO_4^{3-} ($molL^{-1}$) ($\times 10^{-3}$)

Worksheet 5
Guided Notes.
(Make your own summary)

Identifying Organic Substances
Student Name..

1.
a) What is the "bromine test" used for?

b) What constitutes a "positive" test result?

c) How would you carry out the test for a gaseous compound?

d) What is one limitation of the test?

2.
Outline 3 chemical tests which may help identify an alcohol.

3.
a) One of these tests can be used "in reverse" to identify a carboxylic acid. Explain this.

b) What is the simplest test to help identify a carboxylic acid?

4.
a) Why is the carbon-13 isotope "targeted" in the use of NMR for organic analysis?

b) What does each "peak" on a ^{13}C-NMR spectrum graph represent?

c) Does the number of peaks in the spectrum correspond to the number of carbon atoms? Explain.

5.
a) Outline the Physics behind Mass Spectrometry.

b) What can MS reveal for a pure element?

c) Why do organic compounds give a multitude of "peaks" on an MS spectrum graph?

d) What is the the significance of the "M$^+$ peak"?

6.
a) What is the underlying Physics for IR Spectroscopy?

b) Mark on this grid (with labelled arrows) where to look for indications of:
i) O-H bonds in an alcohol.
ii) O-H bonds in a carboxylic acid.
iii) C=O bonds
iv) C=C bonds
v) C-C (single) bonds

IR Spectrum

Transmittance (%)
100
0

Wave Number (cm^{-1})
4000   3000   2000   1500   1000   500
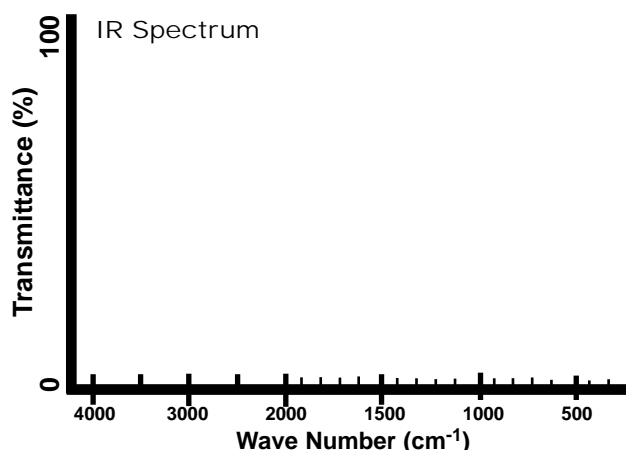
c) Explain why it often not very useful to look for the "signature" signal from C-H bonds.

Worksheet 6   Interpreting Spectra Graphs

Student Name.......................................

1. C-13 NMR Spectra
Sketch the structure of each compound named below, then match each one to its C-13 NMR spectrum. Justify your choice in each case.
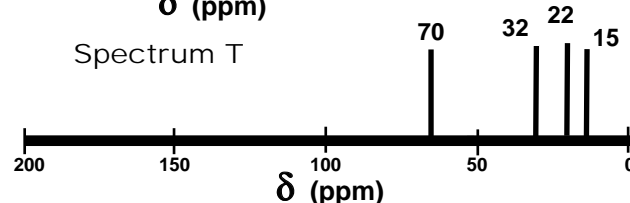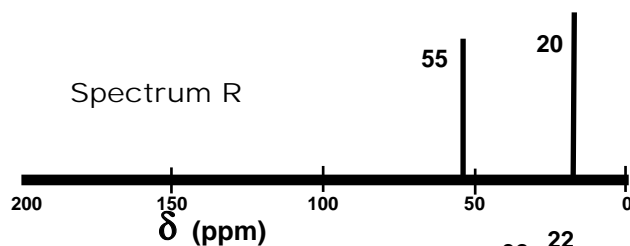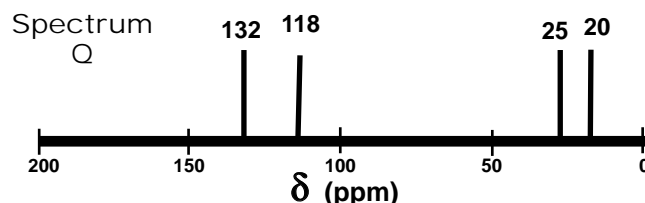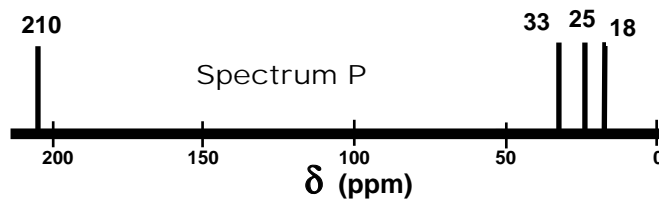
butane

1-butene

1-butanol

2-butanone

2,3-dichlorobutane

Spectrum P

210   33 25 18

200   150   100   50   0
δ (ppm)

Spectrum Q

132 118   25 20

200   150   100   50   0
δ (ppm)

Spectrum R

55   20

200   150   100   50   0
δ (ppm)

Spectrum S

28 20

200   150   100   50   0
δ (ppm)

Spectrum T

70   32 22 15

200   150   100   50   0
δ (ppm)
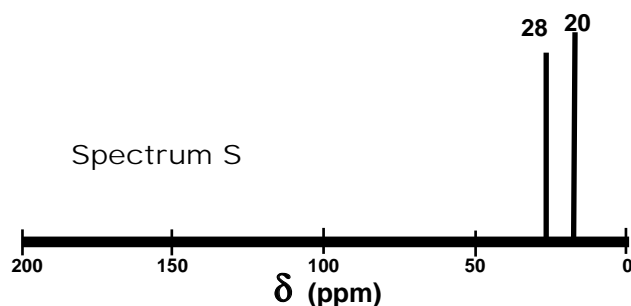
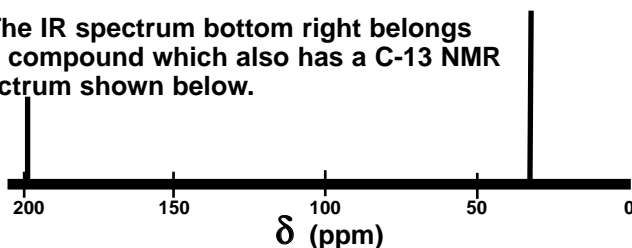### 2. IR Spectra
a) For the IR spectrum at right,
i) use your Data Sheet to suggest the likely bond types responsible for each trough A,B, C, etc.

A   B   C   D   E

Transmittance (%)
100

0
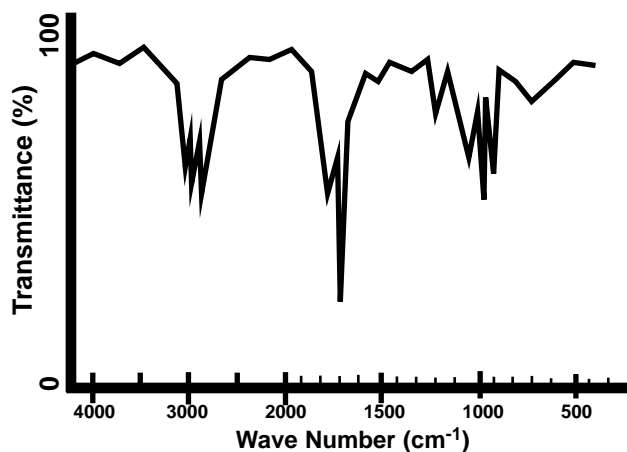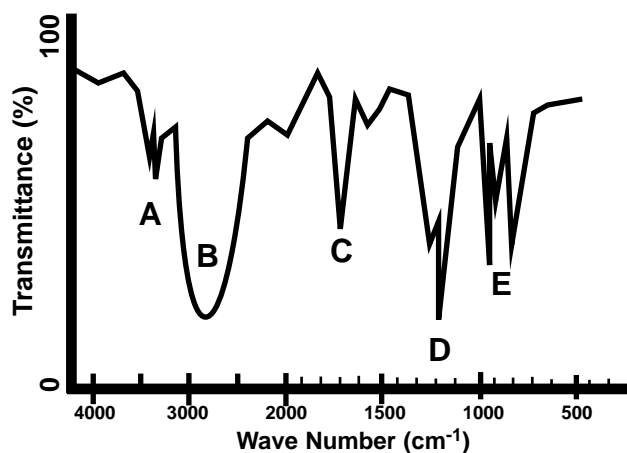4000   3000   2000   1500   500
Wave Number (cm^{-1})

ii) suggest the homologous series it probably belongs to.

iii) Given that its empirical formula is CH_2O, name it.

b) The IR spectrum bottom right belongs to a compound which also has a C-13 NMR spectrum shown below.

200   150   100   50   0
δ (ppm)

Aditionally, its MS spectrum shows an M$^+$ peak at 58. What is it? Give all your reasoning.

Transmittance (%)
100

0
4000   3000   2000   1500   1000   500
Wave Number (cm^{-1})

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Worksheet 7
Guided Notes.
(Make your own summary)

Outline the significance of each of the following factors in the design of a chemical synthesis process.

1. Need for, and uses of the chemical.

2. Availability of raw materials

3. Reaction conditions

Chemical Synthesis & Design
Student Name.....................................

4. Yield & purity

5. Environmental & social issues.
(Give an outline of a serious case of negligence you have researched.

Worksheet 8   Case Study of a Chemical Process

Fill in the blanks

Student Name.....................................

Ammonia is used in the manufacture of
a)............................. for agriculture, and for
b)....................... acid. This, in turn, is used to
manufacture c)............................., ... and
....

Until the early 20th century, manufacturing these
things depended on the supply of d)............................
mined in natural deposits in e)......................... In
1908, Fritz f)........................ developed a method to
make ammonia from g)...................... and ....
This was enormously significant for Germany which
could continue making h)............................ and
.... during World War 1.

The reaction to make Ammonia is not an easy one.
At room temperature and pressure, the reaction rate
is very i)....................., and the equilibrium lies well to
the j)....................., favouring the k)..............................

l)....................... temperatures increase the reaction
rate, but also shift the equilibrium to the m)...............,
because the reaction is n).............-thermic.

The modern production of ammonia by the
o)...................... Process is a balancing act between
reaction energy, reaction p).................... and the
q)............................, to achieve efficient and
economical production.

The reactant gases are mixed in the ratio 3 parts
r)........................... to 1 part s)...........................
and combined at a pressure of t)...........................
atmospheres. This high pressure forces the
equilibrium to the u)...........................

The reaction mixture is heated to approximately
v)............. ^oC. This temperature is a compromise
between increased w)............................ and the
x)................................, which shifts left at higher
temperatures.

A catalyst of y)............................. lowers the
z)........................... energy and speeds up the rate.
This allows a aa)..............................., more
economical temperature to be used.

The reaction mixture flows out of the reaction
chamber to a ab)..................................... where
ammonia is ac)......................... Unreacted hydrogen
& nitrogen are ad)................... ....

To ensure efficient production, monitoring of the
reaction mixture ratio, ae)........................... and
.... is required. The presence of
contaminating gases (such as af)...........................
and ....) is important too, since
these could ag)........................... the catalyst, if
allowed to build up.

Answer Section

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Worksheet 1

1.
a) Not Pb or Ag   **b) Not Ba or Ca**
c) indicates Cu2+
d) not CO3   **e) not PO4 or OH**
f) indicates SO4   **Must be <u>copper(II) sulfate</u>**

2.
a) not Ba or Ca   **b) indicates Fe2+**
c) not SO4   **d) probable Cl**
Probable iron(II) chloride

3.
To verify chloride use complexation test on the pptte from the last test.
Add drops of dilute ammonia soln.
If pptte redissolves, presence of Cl is confirmed.

4.
calcium carbonate

5.
Chloride addition indicates either Pb or Ag.
Both these will also pptte with hydroxide, but only Pb(OH)$_2$ will redissolve in excess OH.
Cation must be Pb.

6.
a) Adding Cl did not pptte, so NOT Pb or Ag.
Sulfate addition gave pptte, so must be Ba or Ca.
b) Flame test.
c) red-orange flare = Ca.   Lime green = Ba

7.
Pptte with Ba suggests sulfate anion.
No pptte with Cl or SO4 eliminates cations Pb, Ca, Ba & Ca.
White pptte with OH suggests Mg cation.
Conclusion: MgSO$_4$

8.
When acid is added to ethanoate ion it forms ethanoic acid:
$CH_3COO^- + H_3O^+ \longrightarrow CH_3COOH + H_2O$
which smells of vinegar. (only because it is!)

Worksheet 2

a) detect/identify
b) measure quantity or concentration
c) eutrophication   d) plant growth
e) removes the oxygen
f) sewerage & fertilisers
g) accumulate   h) permanent brain damage
i) leaded petrol   j) precipitation
k) flame   l) lime-green
m) brick-red   n) blue
o) Atomic Absorption Spectroscopy
p) light   q) frequencies/spectrum
r) frequencies   s) absorption
t) trace   u) cobalt
v) lead

Worksheet 3

1.
a)   i) Soil sample = 54.27 - 42.85 = 11.42g
          ii) Water = 54.27 - 52.66g = 1.61g
          iii) Organic = 52.66 - 46.72 = 5.94g
          iv) Minerals = 46.72 - 42.85 = 3.87g

b) %water = (1.61/11.42)x100 = 14.1%
  % organic = (5.94/11.42)x100 = 52.0%
  % minerals = (3.87/11.42)x100 = 33.9%

c) Step 4. Burning (combustion) is a chemical change.
d) To ensure that it was thoroughly dried before weighing.

2.
a) $Ag^+_{(aq)} + Cl^-_{(aq)} \longrightarrow AgCl_{(s)}$

b) moles of AgCl: n = m/MM   MM= 143.3g
                     = 3.42 / 143.3
                     = 0.02387 mol   (ratio 1:1)
  ∴ moles of chloride = 0.02387 mol   (ratio 1:1)
  mass chloride: m = n x MM   MM(Cl⁻)= 35.45g
                     = 0.02387 x 35.45
                     = 0.846 g
∴ % chloride in sample = <u>0.846</u> x 100 = 1.69%
                          50.0

3.
  moles of BaSO$_4$:   n = m/MM   MM= 233.4g
                     = 3.27 / 233.4
                     = 0.0140 mol
  ∴ moles of sulfate = 0.0140 mol   (ratio 1:1)
  mass of sulfate: m = n x MM   MM(SO$_4$)= 96.1g
                     = 0.0140 x 96.1
                     = 1.35 g

∴ % sulfate in sample = <u>1.35</u> x 100 = 30.3%
                        4.46

Worksheet 4

1.
a) $Pb(NO_3)_{2(aq)} + 2NaI_{(aq)} \longrightarrow PbI_{2(s)} + 2NaNO_{3(aq)}$
b)

End Point = 24mL
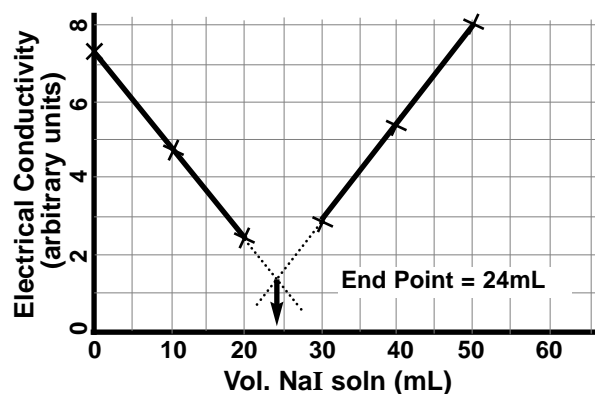
c) over page

Answer Section

Worksheet 4 (cont.)

1.
c) At end-point, moles of iodide ion added is:
         $n = c.V = 0.140 \times 0.024 = 0.00336$ mol.
so, n(Pb) = 0.00336 / 2   (mole ratio 1:2)
              = 0.00168 mol. Pb in 25ml aliquot.

so, n(Pb) in sample = 0.00168 x20 = 0.0336 mol.
mass(Pb)   m = n x MM   (MM = 207.2)
                    = 0.0336 x 207.2
                    = 6.96 g
% Pb = (6.96 / 8.62) x 100 = 80.8 %

2.
a)

Solution No.	1.	2.	3.	4.	5.	6.
Concentration (molL^{-1}) (x10^{-3})	5.00	4.00	3.00	2.00	1.00	0
% Absorbance	62	50	38	24	13	0
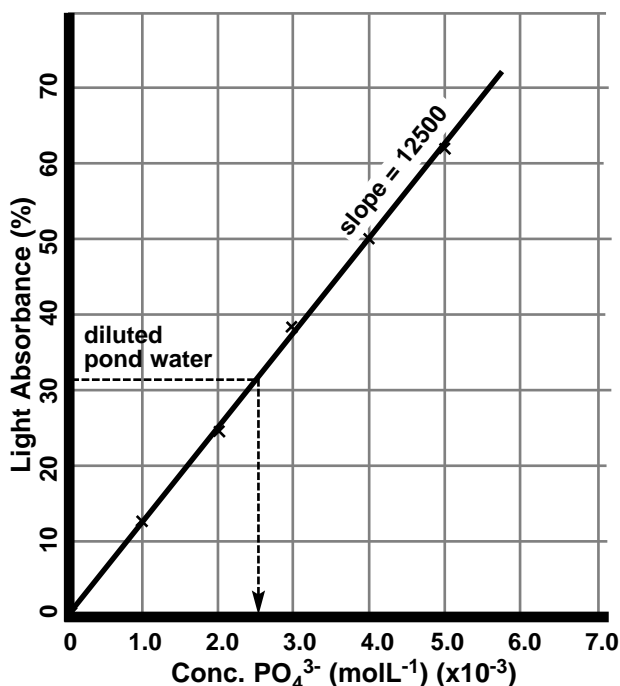
b) Concentration of test sample:
(read from graph scale, or use calibration gradient)

31% absorbance gives conc. = 2.48x10^{-3} molL^{-1}.
(conc. of diluted sample)
So, conc. in original pond water = 4.96x10^{-2} molL^{-1}.

Worksheet 5

1.
a) Identifies compounds containing C= C bonds.
b) Loss of colour from the Br$_2$ solution.
c) Bubble the gas through the bromine soln.
d) Also reacts with triple bonds & cannot differentiate double from triple bonds.

2.
Sodium metal test: sodium produces bubbles of
H$_{2(g)}$ in (non-aqueous) sample.
Iodoform test: adding NaOH and iodine soln.
produces a characteristic pale yellow cloudy pptte of
iodoform, **CHI$_3$ after warmed.**
Ester reaction: adding sulfuric acid catalyst, plus
glacial ethanoic acid (and warm) produces "fruity"
smelling esters if an alcohol is present.

3.
a) The "ester reaction" can be used to detect a carboxylic acid. Add sulf.acid catalyst and ethanol and warm.
b) Add water and test with blue litmus or other indicator to look for acidic solution.

4.
a) The common isotope C-12 does not "feel" magnetic fields so it gives no signals during NMR. C-13 does returns signals, so it is the target.
b) A signal from C-13 atoms which have resonated with particular frequencies of RF energy while in a magnetic field. The signal's deviation from a reference molecule (TMS) gives clues about the electronic environment in each part of the molecule.
c) It will if every carbon in the molecule is in a slightly <u>different</u> electronic environment.
If 2 (or more) carbons are in exactly the same environment, they will return a single, more intense signal.

5.
a) Atoms or molecules are ionised, accelerated by electric fields then enter a magnetic field. The ions follow slightly different paths according to their mass. The different detection positions form a spectrum graph with peaks corresponding to their different masses.
b) Shows the different isotopes of the element and their relative abundance in the sample.
c) Organic molecules tend to disintegrate into many fragments during the ionisation process. Each different mass fragment returns a separate peak on the spectrum.
d) The highest mass peak (M+) of any significance is usually the entire molecule with an ionic charge. The mass value of M+ can be taken to be the mass of the molecule itself.

6.
a) Chemical bonds act like springs & can wiggle & stretch, etc. To gain the energy to do this, they can absorb infra-red energy at particular wavelengths of IR. Measurement of exactly which wavelengths have been absorbed or not, gives a "fingerprint" of the types of bonds present.
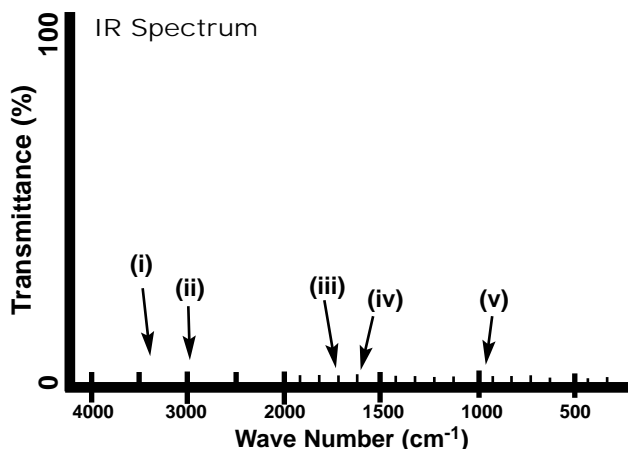
b) over.

Answer Section
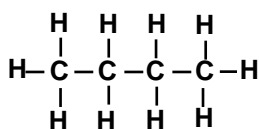
Worksheet 5 (cont.)

6.
b)

c) Firstly, C-H bonds are common in most organic compounds, so detecting them tells you very little. Secondly, they are often obliterated by signals from O-H bonds at similar wavelengths.
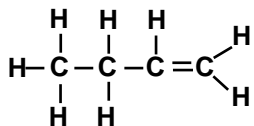
Worksheet 6

1. In all following explanations the C atoms are numbered from right to left.
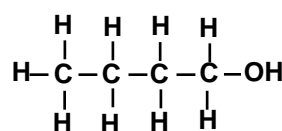
butane

C-atoms 1 & 4 are in identical "electronic environments". So are C-atoms 2&3. Therefore, we look for only 2 peaks, both in the range 10-50 ppm.
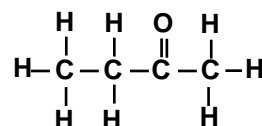<u>Matches spectrum"S"</u>

1-butene

All C-atoms are in different "electronic environments". So we look for 4 peaks. Two will be in 90-150 range (C=C) and 2 in the range 10-50 ppm. (C-C)
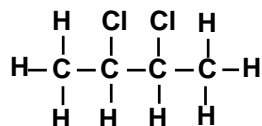<u>Matches spectrum"Q"</u>

1-butanol

All C-atoms are in different "electronic environments". So we look for 4 peaks. One will be in 50-90 range (C-O) and 3 in the range 10-50 ppm.
<u>Matches spectrum"T"</u>

2-butanone

All C-atoms in different environments, so 4 peaks. One will be around 200 (C=O) and 3 in the range 10-50 ppm.
<u>Matches spectrum"P"</u>

2,3-dichlorobutane

C-atoms 1&4 are in identical environments. So are C-atoms 2&3. Therefore, we look for only 2 peaks. One in range 10-70, (C-Cl) the other 10-50 ppm.
<u>Matches spectrum"R"</u>

2.
a) i)   **A = probable C-H bonds.** (Not N-H from given info.)
   B = probable O-H in acid.
   C = prob. C=O.   (confirms acid COOH)
   D = prob. C-O
   E = prob. C-C
ii) carboxylic acid.
iii) Matches with ethanoic acid.

b) The IR spectrum has a deep trough at 1700 cm^{-1} suggesting a C=O bond. Other troughs are probable C-C and C-H bonds only.

This matches the NMR peak at about 200 ppm (C=O) and well-shielded (C-H and C-C) carbon atom(s) at about 35 ppm. This second peak is higher, perhaps suggesting 2 or more carbons in identical environments(?)

M+ peak at 58, so formula mass = 58.

If molecule contains 1 oxygen atom, then maximum 3 carbons. Need 6 hydrogens to add to 58, so likely formula C_3H_6O.

This matches both propanone <u>and</u> propanal...

but <u>propanone</u> best fits the NMR spectrum since both its CH3 groups are in identical bonding environments.

Worksheet 7

1. Need & uses.
Obviously, we only go to the trouble of synthesis of chemicals that ARE needed or wanted.
2. Raw Materials.
Very important to find starting raw materials which are readily available and preferably cheap.
3. Reactions conditions.
These determine if you need to plan for high pressure vessels, heating, cooling, etc. and (for example) if pipes & tanks need to be glass, stainless steel or plastic.
4. Yield & purity
It is vital to know the reaction equilibrium characteristics, its enthalpy & entropy changes & any effective catalysts. Manipulating pressures, temps, catalysts, etc. allows yield to be maximised at good reaction rates.

The product(s) may need to be distilled, recrystallised, etc. to be purified. This must be part of the planned process.

5. Environment & social
Wastes, spillage, etc. must be contained & treated appropriately to avoid disasters such as at Bhopal (India) in 1984 when toxic fumes escaped from a chemical plant & killed approx 4,000 people & injured as many as 500,000.

Answer Section

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Worksheet 8

a) fertilisers   **b) nitric**
c) explosives, pigments, fibres/plastics
d) saltpetre (sodium nitrate)
e) Chile   **f) Haber**
g) hydrogen & nitrogen
h) explosives & fertilisers
i) slow   **j) left**
k) reactants   **l) higher**
m) left   **n) exothermic**
o) Haber   **p) rate**
q) equilibrium   **r) hydrogen**
s) nitrogen   **t) 300**
u) right   **v) 400**
w) reaction rate   **x) equilibrium**
y) iron   **z) activation energy**
aa) lower   **ab) condenser**
ac) liquified
ad) pumped back into the reaction chamber.
ae) temperature & pressure
af) carbon monoxide and sulfur compounds
ag) poison