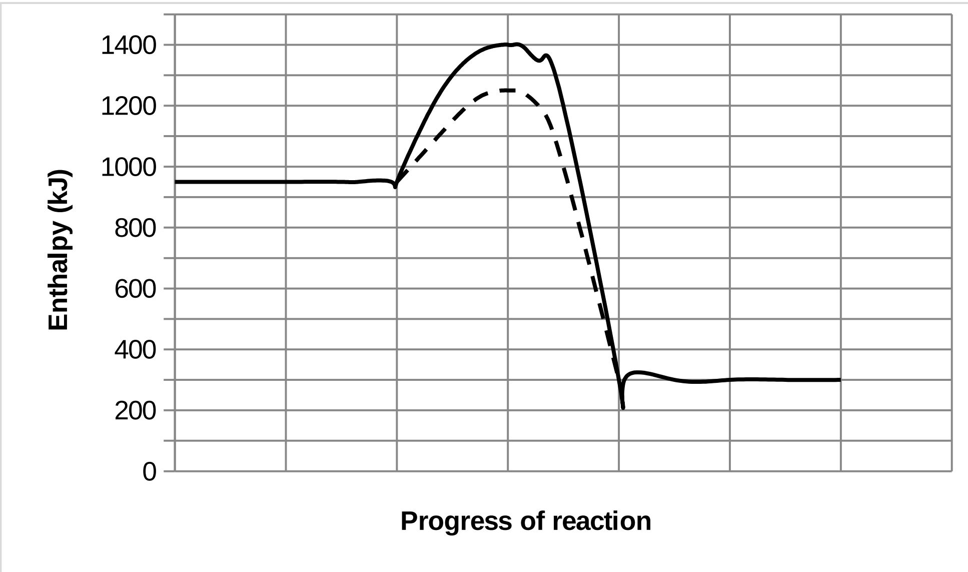
Section One: Multiple-choice **20% (40 marks)**

1. C	**2. B**	**3.C**	**4. B**	**5. D**
6. B	**7. D**	**8. C**	**9. B**	**10. A**
11. D	**12. C**	**13. C**	**14. C**	**15. A**
16. A	**17. C**	**18. C**	**19. A**	**20.C**

Section Two: Short answer **35% (70 marks)**

Question 26 **(8 marks)**

Consider the energy profile diagram shown below.



(a) State the value of ΔH for this reaction and classify this reaction as endothermic or exothermic. (2 marks)

- **ΔH = -650 kJ mol $^{-1}$**
- **exothermic**

(c) Define 'activation energy' and state the value of E_a for this reaction. (2 marks)

- **minimum energy required before a collision between particles can be successful**
- **E_a = 450 kJ mol $^{-1}$**

(d) Include this information on the energy profile diagram given. (1 mark)

- **(see above, ensure transition state at 1250 kJ)**

(e) Define the term 'nanomaterials'. What possible advantage could be provided by having the metal catalyst in nanoparticle form, rather than as a sheet or block of metal? (3 marks)

- **materials containing particles in the size range 1-100 nanometres**
- **such small particle size provides huge surface area**

- **therefore more catalytic sites available for the reactants to come into contact with and higher effectiveness, increasing reaction rate**

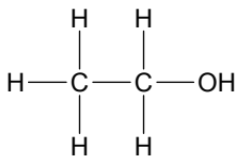
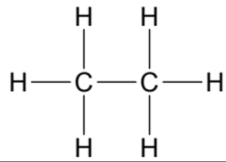
Question 27 **(5 marks)**

Explain each of the following scenarios that relate to the physical and chemical properties of water.

(a) If you look at a spider web after a storm, you will often see that the rain has formed hundreds of tiny water beads clinging to the threads of the spider web, rather than a continuous film of water along the silk threads. (2 marks)

- **high surface tension of water**
- **the strong hydrogen bonding between water molecules 'pulls' surface water molecules inwards towards the rest of the water**
- **this results in the tendency of water to bead instead of spreading out, in order to produce the lowest surface area possible**

(b) Ethanol is soluble in water, whereas ethane is not soluble. (3 marks)

Ethanol	Ethane
	
soluble	not soluble

- **water is highly polar and forms strong hydrogen bonds between its molecules, and will therefore dissolve substances with similar strength IMFs**
- **ethanol has the ability to form hydrogen bonds and is therefore soluble in water**
- **ethane has only dispersion forces and is therefore insoluble**

Question 28 **(9 marks)**

(a) Which Period 3 element has the; (3 marks)

(i) smallest atomic radius? **argon**
(ii) highest electronegativity? **chlorine**
(iii) lowest ionisation energy? **sodium**

(b) Explain why magnesium atoms form cations with a 2+ charge, but chlorine atoms form anions with a 1- charge. (4 marks)

- **atoms will often react to achieve a more stable electron arrangement by gaining or losing electrons, forming charged ions, thus achieving a noble gas configuration.**
- **Elements with low number of valence electrons usually lose, elements with high number usually gain.**
- **magnesium has 2 valence electrons, which it will lose in order to achieve a stable octet, thus forming a cation. This results in formation of a 2+ charge because the magnesium now has 2 more protons than electrons**
- **chlorine has 7 valence electrons, so it will obtain one more to achieve a stable octet, forming an anion with an overall charge of 1-**

(c) Define the term 'isotope' and name the Period 3 element which would be an isotope for an atom with the following subatomic particle arrangement. (2 marks)

protons = 15 neutrons = 15 electrons = 15

- **atoms with the same number of protons (atomic number) but different number of neutrons (therefore a different mass number)**
- **phosphorus**

Question 29 **(6 marks)**

Consider the eight (8) substances below. Using **only** these substances, answer the following questions by selecting appropriate substances from this list.

$NaOH(aq)$	$CuCO_3(s)$	$HCl(aq)$	$NaHCO_3(s)$
$SiO_2(s)$	$NH_4Cl(aq)$	$Zn(s)$	$K_2SO_4(aq)$

(a) Explain, using the Arrhenius model and a chemical equation, why one of these substances is classified as a strong base. (2 marks)

- **$NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$**
- **Arrhenius theory states that bases are substances that produce OH^- ions in solution**

(b) Name two (2) substances that could be used to neutralise each other. (1 mark)

any pair below…
- **NaOH and HCl**
- **NaOH and NH_4Cl**
- **HCl and $CuCO_3$**
- **HCl and $NaHCO_3$**

(c) Write an equation for the reaction between two (2) substances that would produce a colourless, pungent-smelling gas when mixed. (1 mark)

- **$OH^-(aq) + NH_4^+(aq) \rightarrow NH_3(g) + H_2O(l)$ (1m)**
  OR
- **$NaOH(aq) + NH_4Cl(aq) \rightarrow NaCl(aq) + NH_3(g) + H_2O(l)$ (1m)**

  (allocate 1m for identifying reactants as NaOH and NH_4Cl)

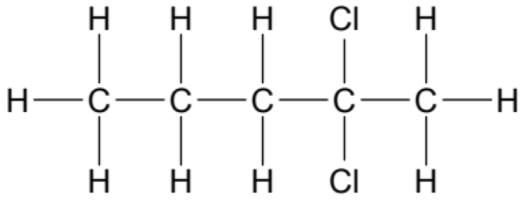
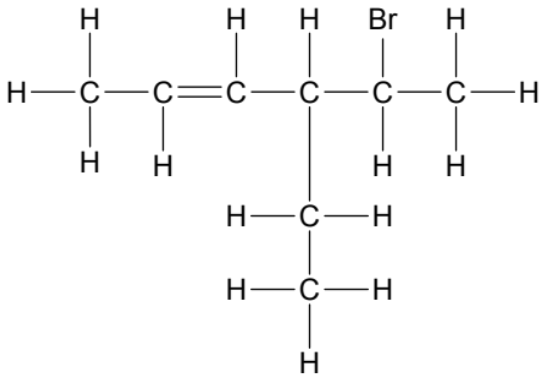
(d) What would be observed upon mixing $CuCO_3(s)$ and $HCl(aq)$? (2 marks)

- **green powder dissolves in colourless solution**
- **colourless gas and blue/green solution formed**

Question 30 **(8 marks)**

Consider the two **incorrectly named** organic substances in the table below.

(a) Draw structural diagrams, showing all bonds, for the organic substances named, and then give each its correct IUPAC name. (4 marks)

Incorrect name	Structural diagram	IUPAC name
1-methyl-3,3-dichlorobutane		**2,2-dichloropentane**
2-bromo-3-ethyl hex-4-ene		**5-bromo-4-ethyl hex-2-ene**

The nature of the bonding within different hydrocarbons determines their chemical properties.

(b) Explain why alkenes are able to undergo addition reactions but alkanes and benzene are not. (4 marks)

- **addition reactions require the presence of a double bond, which is present in alkenes**
- **this double bond is converted ('broken') to a single covalent bond and another substance (halogen, hydrogen, hydrogenhalide, water etc) is incorporated, one group adding to the carbon on each side of the double bond**
- **alkanes do not have a double bond and can only undergo substitution reactions**
- **benzene similarly does not contain double bonds, the ring structure is very stable and can also only undergo substitution reactions**

- **(adding to an alkane or benzene would result in C having more than 4 bonds)**

Question 31 **(6 marks)**

An empty balloon skin was found to weigh 3.7 g. It was then filled with 7.1 L of helium gas at STP.

(a) Calculate the total mass of the balloon after filling. (3 marks)

n(He) = V / 22.71
= 7.1 / 22.71
= 0.312638 mol

m(He) = nM
= 0.312638 x 4.003
= 1.2515 g

total mass of balloon = 3.7 + 1.2515
= 4.9515 g
= 5.0 g (2SF)

(b) Why does the helium balloon now float even though its total mass is greater? (1 mark)

- **overall density is lower than air now**

(c) Explain the following in terms of the kinetic theory why the volume of the sealed balloon decreased when it was taken outside on a snowy day where the temperature was -8 ˚C. (2 marks)

- **decreased temperature decreases average kinetic energy of particles**
- **this results in slower and less collisions with the walls of the elastic container (balloon), therefore the pressure is lowered and the volume decreases**

Question 32 **(6 marks)**

(a) For each of the individual substances, complete the table below by stating; (3 marks)

(i) the type of interatomic bonding present, and
(ii) whether or not each substance, when considered in isolation, would conduct electricity.

	(i) type of interatomic bonding present (i.e. metallic / ionic / covalent)	(ii) ability to conduct electricity (i.e. yes / no)
Mg(s)	**metallic**	**yes**
$MgCl_2$(aq)	**ionic**	**yes**
H_2(g)	**covalent**	**no**

(-½ m per mistake)

(b) Explain your answers to (a) part (ii) in terms of the structure and bonding present in the substances. Use equations to support your answer where appropriate. (3 marks)

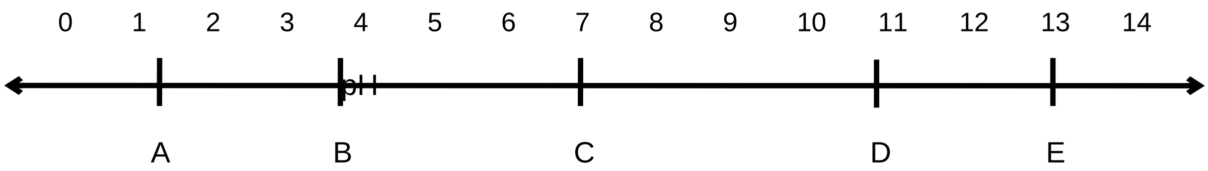
- **Mg metal has delocalised electrons (mobile charge) therefore able to conduct**
- **$MgCl_2$ is soluble in water and therefore ions become dissociated (mobile charge) allowing electrical conductivity**
- **$MgCl_2 \rightarrow Mg^{2+} + 2\ Cl^-$**
- **H_2 is composed of discrete diatomic molecules with no mobile charge therefore unable to conduct**

Question 33 **(8 marks)**

A student was given the five (5) solutions listed below, each with a 0.05 mol L^{-1} concentration.

KOH NaCl H_2CO_3 HNO_3 NH_3

He then used universal indicator to determine the pH of each solution and plotted his results on the pH line shown.



(a) Complete the table below with the student's expected results. (5 marks)

	Identity of substance	Colour in universal indicator
A	**HNO_3**	**red**
B	**H_2CO_3**	**pink / orange**
C	**NaCl**	**green**
D	**NH_3**	**blue / purple**
E	**KOH**	**purple**

(-1m per mistake)

(b) Name the substance that would have the highest concentration of H^+ ions. (1 mark)

- **Nitric acid**

(c) Write successive ionisation equations to illustrate how H_2CO_3 behaves in water. (2 marks)

- $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ **OR** $H_2CO_3 + H_2O \rightleftharpoons H_3O^+ + HCO_3^-$
- $HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$ **OR** $HCO_3^- + H_2O \rightleftharpoons H_3O^+ + CO_3^{2-}$

End of Section Two

Section Three: Extended answer **40% (64 marks)**

Question 34 **(16 marks)**

Fluoridation is performed by adding hexafluorosilicic acid (H_2SiF_6) into our water, which when dissolved, releases the fluorine contained within the compound as fluoride ions (F^-).

(a) Calculate the percent composition by mass of fluorine in the compound hexafluorosilicic acid. (2 marks)

$$\textbf{\% F in } H_2SiF_6 = \frac{6 \times 19.00}{144.106} \times 100 = 79.11\ \%$$

A tank containing 20 000 L of water was to be fluoridated by adding hexafluorosilicic acid. If 90.0 mL of 1.660 mol L^{-1} $H_2SiF_6(aq)$ was added to the tank and mixed thoroughly;

(b) Calculate the concentration of fluoride ions (F^-) present in the water and state whether this falls within the range recommended by the Department of Health. (You may assume all the fluorine in the H_2SiF_6 is released into the water as fluoride ions.) (6 marks)

<table>
<tr><td colspan="2">$n(H_2SiF_6) = cV$
$= 1.660 \times 0.0900$
$= 0.1494$ mol</td><td>$c_1V_1 = c_2V_2$

$c_2 = 1.660 \times 0.090 / 20000$*
$= 7.47 \times 10^{-6}$ mol L^{-1}
= dilute $c(H_2SiF_6)$</td></tr>
<tr><td>either</td><td>or</td><td rowspan="2">$c(F^-) = 6 \times c(H_2SiF_6)$
$= 4.482 \times 10^{-5}$ mol L^{-1}

i.e. 4.482×10^{-5} mol in 1 L</td></tr>
<tr><td>$n(F^-$ released$) = 6 \times 0.1494$
$= 0.8964$ mol</td><td>$m(H_2SiF_6) = nM$
$= 0.1494 \times 144.106$
$= 21.5294$ g</td></tr>
<tr><td>$m(F^-) = nM$
$= 0.8964 \times 19.00$
$= 17.0316$ g</td><td>$m(F^-) = \%F \times m(H_2SiF_6)$
$= 79.11/100 \times 21.5294$
$= 17.0316$ g</td><td rowspan="2">$m(F^-$ in 1L$) = nM$
$= 4.482 \times 10^{-5} \times 19.00$
$= 8.5158 \times 10^{-4}$ g

$= 0.85158$ mg</td></tr>
<tr><td colspan="2">$m(F^-) = 17031.6$ mg</td></tr>
<tr><td colspan="2">$c(F^-)$ = mass in mg / volume in L
$= 17031.6 / 20000$*
$= 0.85158$ mg L^{-1}
$= 0.852$ mg L^{-1} (3SF)</td><td>i.e. $c(F^-) = 0.85158$ mg L^{-1}
$= 0.852$ mg L^{-1} (3SF)</td></tr>
<tr><td colspan="3">Yes, this would provide a fluoride concentration within the recommended 0.6-1 mg L^{-1} range

* Note – if students have used 20000.09 L, the final answer remains the same</td></tr>
</table>

(c) Other than fluoridation, name and briefly describe one other process our ground or sea water may be subject to, before joining the main water supply. (2 marks)

any suitable answer, for example;

- **chlorination, to oxidise organic compounds**
- **aeration, remove dissolved gases**
- **filtration, to remove solid particles**
- **disinfected, kill bacteria and viruses**
- **precipitation, remove excess metal ions**
- **desalination, remove salt from seawater**

The amount of lead present in a given sample of water can be accurately determined by atomic absorption spectroscopy (AAS). Analysis by AAS relies on knowledge of the absorption / emission spectrum of the element lead.

(d) Describe how the absorption and emission spectrum of an element is related to electron energy levels, and how this is utilised in AAS. (6 marks)

- **the electrons of an atom are confined to specific energy levels or shells**
- **electrons are able to move between these shells by absorbing (to jump outwards to a higher energy level ie further from the nucleus) or emitting (to fall inwards to a lower energy level ie closer to the nucleus) particular amounts of energy**
- **the amount of energy absorbed or emitted by these electrons as they move between shells corresponds to particular wavelengths/frequencies of light which create the corresponding absorption or emission spectra**
- **these spectra are unique for each element, since the energy levels of the electrons shells are slightly different for each element**
- **in AAS the known absorption spectrum of a particular element is used and light of a corresponding wavelength/frequency is shone through the sample being tested**
- **the higher the concentration of the particular element in the sample, the more light it absorbs**

Question 35 **(17 marks)**

A chemist decided to run some tests to compare the aspartame levels found in four different types of soft drink, and she used HPLC to perform the analysis.

(a) Discuss the chemical principles behind the process of HPLC by answering the following questions. (6 marks)

(i) What physical properties must a sample have to make it appropriate for HPLC analysis to be used?

- **samples can not be in gaseous form**
- **samples must be soluble to a degree in the particular solvent being used so that a liquid sample can be prepared**

(ii) Describe how HPLC is able to separate the components of a sample, in particular focussing on the role of polarity in the process.

- **either a polar solvent (mobile phase) is used with a non-polar stationary phase or a non-polar solvent (mobile phase) can be used with a polar stationary phase**
- **the sample to be analysed/separated is dissolved in the mobile phase and moves through the HPLC column**
- **the components of the sample will adhere to the stationary phase with different strengths due to the varying polarity of each component (also components will have varying degrees of interaction with the mobile phase)**
- **the components therefore move along the column at differing rates and exit the column at different times, where they can be collected/identified/further analysed**

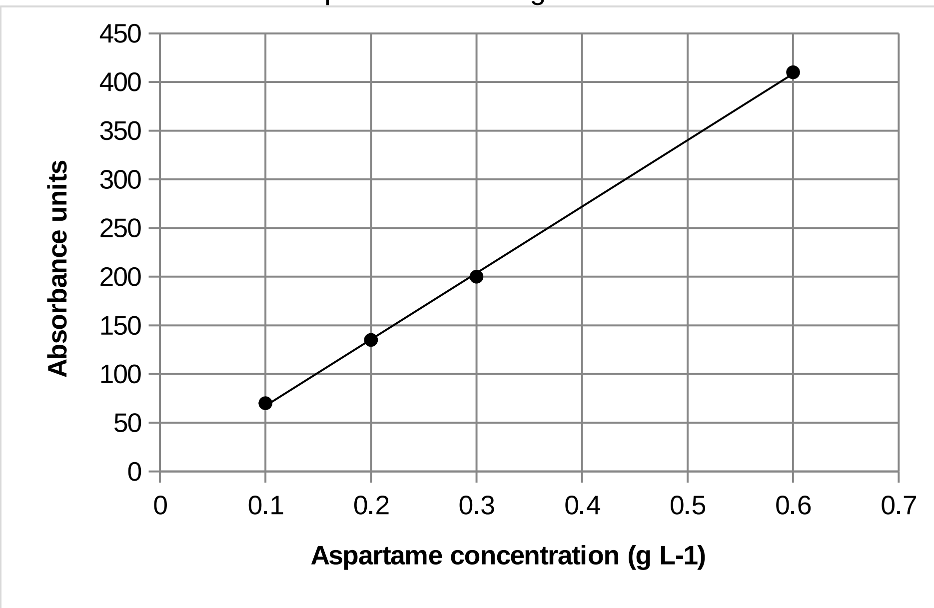
(b) Which of the soft drinks contained aspartame? Name the drink with the highest aspartame concentration. (2 marks)

- **Diet Pepsi, Pepsi Max, Fanta Orange contained aspartame**
- **Diet Pepsi contained the highest level**

The chemist wanted to quantify her data, so she ran HPLC on a series of aspartame standards to produce a calibration curve. The results obtained from this are summarised in the table below.

Aspartame concentration ($g\ L^{-1}$)	**Absorbance units**
0.1	70
0.2	135
0.3	200
0.6	410

(c) Plot the calibration curve for aspartame on the grid below. (4 marks)



(1m x-axis (scale and label), 1m y-axis (scale and label), 1m data points, 1m line of best fit)

(d) List two (2) controlled variables the chemist would have had to consider when performing HPLC on the various aspartame standards. (2 marks)

any 2 of…
- **same temperature**
- **same solvent**
- **same stationary phase**
- **same type of HPLC column**
- **same pressure used**
- **i.e. tests run under same conditions**
- **take absorbance readings at same wavelength**

(e) Use the information from the chromatograms and the calibration curve to calculate the concentration of aspartame (in $mol\ L^{-1}$) in the drink Pepsi Max. (Note: The molar mass of aspartame is 294.3 $g\ mol^{-1}$.) (3 marks)

- **from chromatogram for Pepsi Max, aspartame level is 306 absorbance units (accept values in the range 300-310)**

- **from calibration curve, this corresponds to an aspartame concentration of (accept values in the range) 0.44-0.46 $g\ L^{-1}$**

- **n(aspartame) = 0.44 / 294.3**
  = 1.495×10^{-3} mol

i.e. 1.495×10^{-3} mol L^{-1}

n(aspartame) = 0.45 / 294.3
= 1.529×10^{-3} mol

i.e. 1.529×10^{-3} mol L^{-1}

n(aspartame) = 0.46 / 294.3
= 1.563×10^{-3} mol

i.e. 1.563×10^{-3} mol L^{-1}

(accept values between 1.49×10^{-3} and 1.57×10^{-3} mol L^{-1})

Question 36 **(16 marks)**

(a) Prepare a neat table that the students could use to record the data collected from this experiment. Complete the table by indicating 'PPT' if a precipitate is formed or 'NR' if no precipitate was observed. (4 marks)

	$NaCl(aq)$	$Na_3PO_4(aq)$
$KNO_3(aq)$	NR	NR
$Ni(NO_3)_2(aq)$	NR	PPT
$AgNO_3(aq)$	PPT	PPT
$Ca(NO_3)_2(aq)$	NR	PPT

(2m neat table, 2m correct results)

(b) Write the ionic equation and corresponding observation for the only precipitation reaction that would have occurred when NaCl(aq) was added to the nitrate solutions. (2 marks)

- **$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$**
- **White precipitate forms**

The precipitate formed from the reaction of Na_3PO_4 with $Ca(NO_3)_2$ was taken for further analysis. The molecular equation for this precipitation reaction is given below.

$$3\ Ca(NO_3)_2(aq) + 2\ Na_3PO_4(aq) \rightarrow Ca_3(PO_4)_2(s) + 6\ NaNO_3(aq)$$

(c) If 10 drops of 0.5 mol L^{-1} $Na_3PO_4(aq)$ had been added to the sample containing excess 0.25 mol L^{-1} $Ca(NO_3)_2(aq)$, what mass of precipitate would you expect to produce? You may assume one drop is equal to a volume of 0.05 mL. (4 marks)

$V(Na_3PO_4)$ = $10 \times 0.05 \times 10^{-3}$
= 5.0×10^{-4} L

$n(Na_3PO_4)$ = cV
= $0.5 \times 5.0 \times 10^{-4}$
= 2.5×10^{-4} mol

$n(Ca_3(PO_4)_2)$ = $n(Na_3PO_4)$ / 2
= 1.25×10^{-4} mol

$m(Ca_3(PO_4)_2)$ = nM
= $1.25 \times 10^{-4} \times 310.18$
= 0.03877 g
= 0.04 g (1SF)

The students decided to isolate the $Ca_3(PO_4)_2$ precipitate from the reaction vessel and weigh it to determine if the actual mass matched their theoretical calculated value.

SEE NEXT PAGE

(d) List the steps that could be used by the students to obtain the $Ca_3(PO_4)_2$ precipitate for weighing. (4 marks)

- **pour entire reaction mixture into filter funnel lined with filter paper (weigh dry filter paper, if intending to subtract mass at end)**
- **wash reaction vessel several times and add rinsings into filter paper to ensure all solid PPT transferred**
- **allow filtrate ($NaNO_3$) to move through filter paper while $Ca_3(PO_4)_2$ PPT is captured as residue**
- **wash residue thoroughly with distilled water and allow to dry completely before weighing (subtract mass of dry filter paper if necessary)**

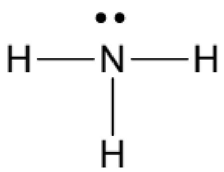
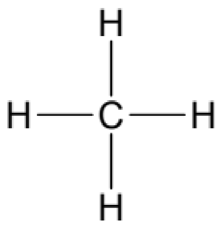
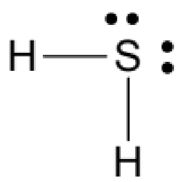
The students found that once they collected and weighed the $Ca_3(PO_4)_2$ precipitate, the mass was slightly lower than that predicted by their calculation.

(e) State one potential source of both random and systematic error in their investigation that may have lead to this discrepancy. (2 marks)

Random error	**accuracy of scales, uneven volume of each of the 10 drops**
Systematic error	**not ensuring complete transfer of PPT to filter funnel, not washing residue thoroughly, not taring scales correctly, some PPT remaining on filter paper when weighing etc**

Question 37 **(15 marks)**

The table below summarises information regarding the boiling points of three (3) covalent molecular substances; ammonia (NH_3), methane (CH_4) and hydrogen sulfide (H_2S).

	Ammonia NH_3	Methane CH_4	Hydrogen sulfide H_2S
Boiling point (°C)	-33	-161	-60
Lewis structure diagram			
Molecular shape	**pyramidal**	**tetrahedral**	**v-shaped / bent**

(a) Complete the table above by drawing Lewis structure diagrams for each of the molecules, as well as stating the molecular shape as predicted by the VSEPR theory. Include all bonding and non-bonding electron pairs in your Lewis diagrams. (6 marks)

(b) Discuss the reasons for the different boiling points of these three substances. (6 marks)

- **methane has the lowest boiling point as it is a symmetrical non-polar molecule**
- **this means it is only able to form weak dispersion forces between molecules**
- **hydrogen sulfide has the second highest boiling point as it is a polar molecule**
- **this allows it to form dipole-dipole forces as well as dispersion forces and contributes to an increase in overall IMF strength**
- **ammonia has the highest boiling point because it is extremely polar, with 3 N-H covalent bonds and a pair of non-bonding electrons**
- **it therefore has the ability to form hydrogen bonds, as well as dipole-dipole and dispersion forces, giving it the strongest IMFs (despite the higher M and therefore stronger dispersion forces in H_2S)**

A 5.78 g sample of one of these 3 gaseous substances had its volume measured at STP and was found to occupy 3.85 L.

(c) Identify which of the compounds this gas was, showing all calculations. (3 marks)

n(gas) = V / 22.71
= 3.85 / 22.71
= 0.16953 mol

M(gas) = m / n
= 5.78 / 0.16953
= 34.1 g mol^{-1}

Therefore gas is H_2S and $M(H_2S)$ = 34.086 g mol^{-1}.

End of questions