Chemistry 3A

Semester One Examination, 2011

Question/Answer Booklet

NAME: Solutions

TEACHER: Dhue

Marker use only

Part	Marks achieved	Marks available
1 Multiple choice	/50	50 (33%)
2 Short answer	/60	60 (40%)
3 Extended answers	/40	40 (27%)
TOTAL		150 (100%)

%

Time allowed for this paper

Reading time before commencing work: Ten minutes
Working time for paper: Two and a half hours

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer Booklet
Separate Multiple Choice Answer Sheet
Separate Chemistry Data Sheet

To be provided by the candidate

Standard Items: Pens, pencils, eraser or correction fluid and ruler
Special Items: A 2B, B or HB pencil for the separate Multiple Choice Answer Sheet and calculators satisfying the conditions set by the Curriculum Council for this subject.

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Chemistry 3A Examination

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MULTIPLE CHOICE ANSWER SHEET

1.	[A]	~~[B]~~	[C]	[D]	16.	~~[A]~~	[B]	[C]	[D]
2.	[A]	[B]	~~[C]~~	[D]	17.	[A]	[B]	[C]	~~[D]~~
3.	[A]	~~[B]~~	[C]	[D]	18.	[A]	[B]	[C]	~~[D]~~
4.	[A]	[B]	[C]	~~[D]~~	19.	[A]	[B]	~~[C]~~	[D]
5.	[A]	~~[B]~~	[C]	[D]	20.	[A]	~~[B]~~	[C]	[D]
6.	[A]	[B]	~~[C]~~	[D]	21.	[A]	[B]	~~[C]~~	[D]
7.	[A]	[B]	~~[C]~~	[D]	22.	[A]	[B]	~~[C]~~	[D]
8.	[A]	~~[B]~~	[C]	[D]	23.	[A]	[B]	~~[C]~~	[D]
9.	~~[A]~~	[B]	[C]	[D]	24.	[A]	[B]	[C]	~~[D]~~
10.	[A]	[B]	[C]	~~[D]~~	25.	[A]	[B]	~~[C]~~	[D]
11.	[A]	[B]	~~[C]~~	[D]					
12.	[A]	[B]	[C]	~~[D]~~					
13.	[A]	[B]	~~[C]~~	[D]					
14.	[A]	[B]	[C]	~~[D]~~					
15.	[A]	[B]	~~[C]~~	[D]					

________ / 25 marks

PART 2 (60 marks)

Answer **ALL** questions in Part 2 in the spaces provided below.

Question 26.

Give fully balanced equations for the reactions which occur (if at all) in the following experiments.
Use **ionic equations** where appropriate. In each case describe observations such as colour changes, precipitate formation (give the colour), or gas evolution (give the colour or describe as colourless) resulting from the chemical reaction.

(a) Sodium carbonate solution is added to excess dilute hydrochloric acid.

Equation $CO_3^{2-}{}_{(aq)} + 2H^+_{(aq)} \rightarrow H_2O_{(l)} + CO_{2(g)}$

[2 marks]

Observation Two clear colourless solution are mixed forming a clear, colourless, odourless gas and a clear colourless solution

[1 marks]

(b) Iron(III) nitrate solution is added to sodium hydroxide solution.

Equation $Fe^{3+}{}_{(aq)} + 3OH^-{}_{(aq)} \rightarrow Fe(OH)_{3(s)}$

[2 marks]

Observation A light brown solution and a clear, colourless solution are mixed forming a brown/yellow precipitate and a clear, colourless solution.

[1 marks]

(c) Dilute sulfuric acid is added to a solution of sodium chromate.

Equation $2H^+_{(aq)} + 2CrO_4^{2-}{}_{(aq)} \rightarrow Cr_2O_7^{2-}{}_{(aq)} + H_2O_{(l)}$

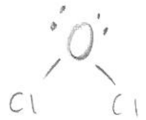
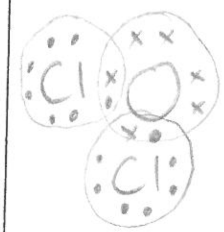
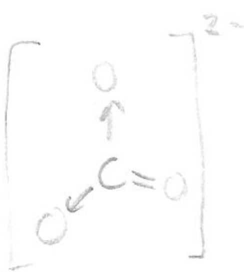
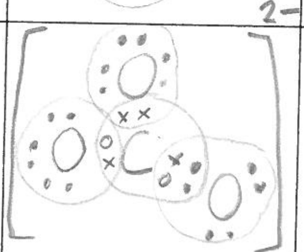
[2 marks]

Observation A clear, colourless solution and a clear, yellow solution are mixed forming a clear dark orange solution

[1 marks]

Question 27.

Complete the table below by drawing correct Lewis (electron dot) diagrams, the molecular shape, indicating whether the substance is polar or non polar.

Formula	Lewis (electron dot) diagram	Name of molecule shape	Polar or non polar
 SO_2		v-shaped (bent)	polar
 PI_3		trigonal pyramidal	polar
 Cl_2O		v-shaped (bent)	polar
 *error CO_3^{2-}		trigonal planar	Not required

[11 marks]

Question 28.

Classify the following solid substances by writing them in the appropriate column in the table below.

silicon carbide	iodine	copper (II) oxide	brass
dry ice (CO_2)	potassium permanganate	sulfur	barium sulphate
solder	graphite	silver	diamond

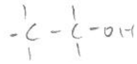
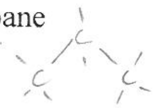
Ionic Solid	Metallic Solid	Covalent Network Solid	Covalent Molecular solid
Copper (II) oxide	brass	Silicon carbide	Iodine
potassium permanganate	solder	graphite	dry ice (CO_2)
barium sulfate	silver	diamond	sulfur

[6 marks]

Question 29.

Classify the following substances according to the **major intermolecular force** found in the substance.


N – N liquid nitrogen liquid hydrogen sulfide liquid carbon disulfide

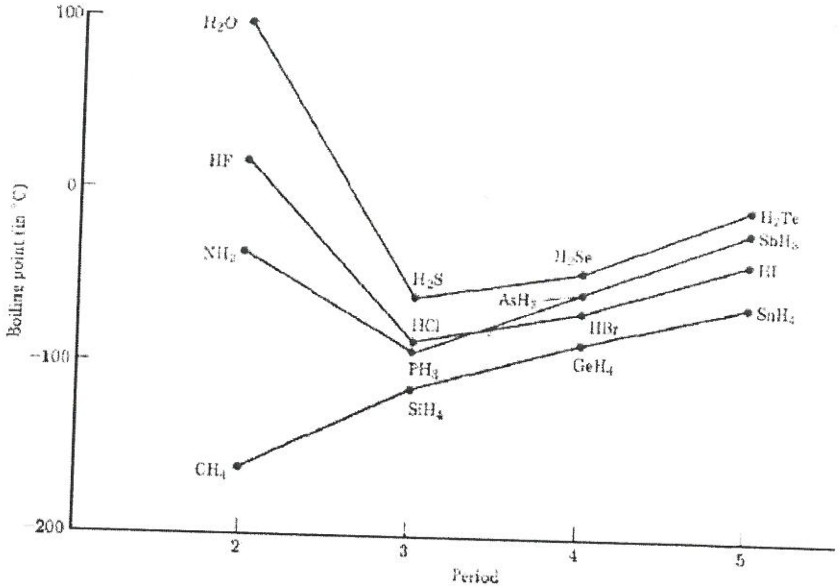

liquid ammonia liquid ethanol  liquid propane 

Dispersion forces	Dipole-dipole	Hydrogen Bonding
liquid nitrogen	liquid hydrogen sulfide	liquid ammonia
liquid carbon disulfide		liquid ethanol
liquid propane		

[3 marks]

Question 30.

The graph below shows the boiling point for the groups 14-17 hydrides plotted against period. Using your knowledge of Van der Waal forces explain the anomalous behaviour of NH_3, H_2O and HF seen in the graph.



extra info

• General trend B.P. increases with increasing molar mass down the periods, but NH_3, HF and H_2O do not follow pattern.

1 • Shared electrons in a covalent bond between two different elements are unevenly shared depending on their electronegativity.

1 • Oxygen, Fluorine and nitrogen are all small highly electronegative elements that form very polar bonds with hydrogen.

1 • NH_3, HF and H_2O molecules have very strong hydrogen bonding due to them being very polar.

1 • these intermolecular forces are much stronger than the other hydrides giving them a higher boiling point.

[4 marks]

Question 31.

Methanol can be made from natural gas by converting the methane in the natural gas to carbon monoxide, CO, and hydrogen, H_2, and then combining these two gases to make the methanol, CH_3OH. This final step involves the equilibrium:

$$CO_{(g)} + 2H_{2\,(g)} \rightleftarrows CH_3OH_{(g)} \qquad \Delta H = -91 \text{ kJ}$$

Complete the table below to show what would happen to the equilibrium concentration of methanol when the following changes are made. Include a short explanation to account for each change applying Le Chateliers principle.

Change made to the equilibrium mixture	**Effect of the change on the equilibrium concentration of methanol. Use the terms *"increases"*, *"decreases"* or *"no change"* AND short explanation**
The equilibrium mixture is compressed to increase the pressure.	• concentration of methanol increases • By increasing pressure the equilibrium will shift to try and decrease the pressure by shifting to the direction with the least gaseous molecules (ie forward reaction)
The equilibrium mixture is cooled to reduce the temperature.	• concentration of methanol increases • A decrease in temperature will shift the equilibrim to increase the temperature by favouring the exothermic reaction. (ie forward reaction)
Additional hydrogen is added to the equilibrium mixture.	• concentration of methanol increases • with an increase in concentration of a reagent, the equilibrium shifts to decrease its concetration by favouring the forward reaction
An appropriate catalyst is added	• no change to the concentration of methanol • A catalyst does not shift the equilibrium position as it effects both forward and reverse reactions evenly.

[8 marks]

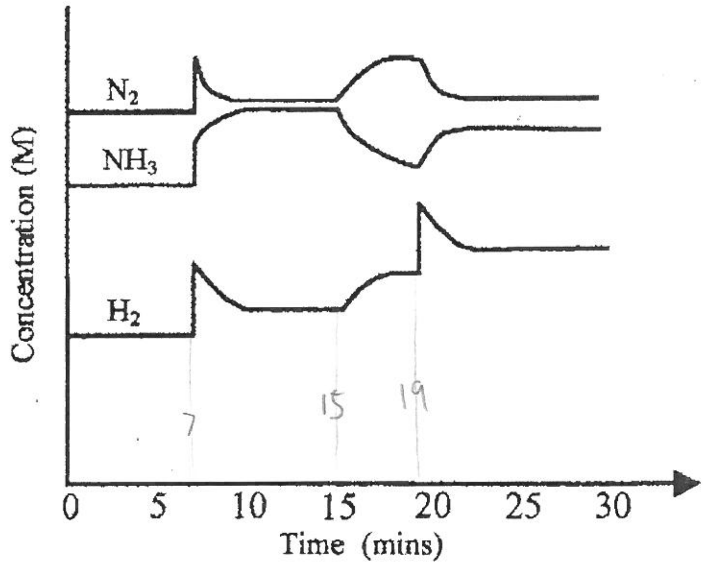
Question 32.

The production of ammonia from nitrogen and hydrogen is an exothermic process according to the equation:

$$N_{2\,(g)} + 3H_{2\,(g)} \rightleftarrows 2NH_{3\,(g)} + 92\text{kJ}$$

Nitrogen, hydrogen and ammonia, at time 0 min are in equilibrium in a reaction vessel at 500 ^{O}C. Changes are made to the conditions of the system after 7 minutes, 15 minutes, and 19 minutes. The effects of these changes are represented in the graph below.

Concentration vs Time Graph



(a) Suggest what particular changes have been imposed at

(i) 7 minutes: Volume of system decreased (Pressure increase) [1 marks]

(ii) 15 minutes: System increased in temperature [1 marks]

(iii) 19 minutes: Addition of some hydrogen gas. [1 marks]

(b) Write the expression for the equilibrium constant for this reaction.

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

[1 marks]

(c) Account for the changes in concentration of the three substances between the 15 minute and the 19 minute mark.

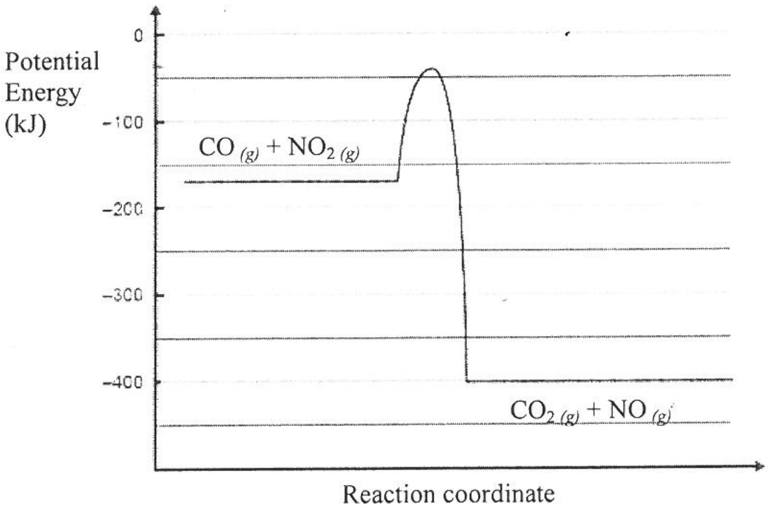
As the forward reaction reagent concentrations increases ($N_2 + H_2$) and the products decrease (NH_3) the equilibrium was shifted to the left ① with no addition or removal of any substance or change in global concentration (due to volume change) the temperature must have been changed, that is to shift left, endothermic, the temperature must have been increased. ①

[2 marks]

Question 33.

The graph below represents the energy changes over the course of a chemical reaction:

$$CO_{(g)} + NO_{2\,(g)} \rightarrow CO_{2\,(g)} + NO_{(g)}$$



(a) Give the magnitude and sign of the ΔH for the forward reaction in kJ

−230 kJ

[1 marks]

(b) Give the activation energy for the reverse reaction in kJ

360 kJ

[1 marks]

(c) Give **two reasons** explaining why the rate of this reaction increases with increasing temperature.

- Ave KE increases, increasing the number of collisions for a given time (particles move faster)
- Larger proportion of particle have sufficient energy to react

[2 marks]

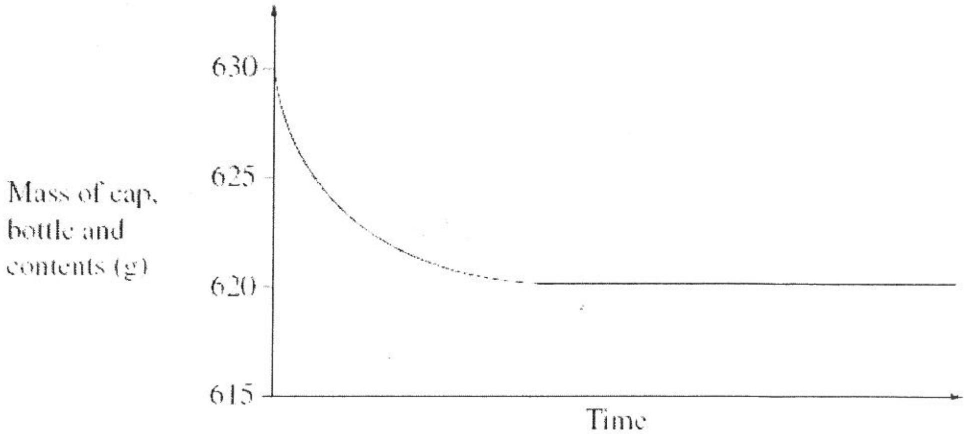
(d) A suitable catalyst is discovered for the reaction. What would be the likely effect of the catalyst on the ΔH ? Explain your answer.

- No change on ΔH as it is only the difference in Enthalpy of products and reactants
- A catalyst only lowers the activation energy

[2 marks]

Question 34.

A bottle of soft drink was placed on an electronic balance and weighed. The cap was removed and placed next to the bottle on the balance. The mass of the cap, bottle and its contents was monitored. The results are shown in the graph. The experiment was conducted at 25°C and 101.3 kPa. Assume that no evaporation has occurred.



(a) Identify the gas released.

Carbon dioxide

[1 marks]

(b) If the soft drinks volume was 500 mL, what was the concentration **in ppm** of the gas in the **initial solution**? (assume density = 1g/mL)

from graph

$m(CO_2) = 10g = 10000mg$ (1)

$ppm = \frac{\text{mass of solute (mg)}}{\text{Mass of solution (kg)}}$

$V(\text{solution}) = 500 mL$

$= 500g = 0.500kg$ (1)

$= \frac{10000}{0.500}$

$= 20000ppm$ (1)

[3 marks]

(c) Calculate the volume of the gas released.

$V(CO_2) = ?$

$n(CO_2) = \frac{m}{M} = \frac{10.0}{44.01} = 2.27 \times 10^{-1} mol$ (1)

$T = 25°C$

$PV = nRT$

$= 298.1 K$

$V(CO_2) = \frac{nRT}{P} = \frac{2.27 \times 10^{-1} \times 8.315 \times 298.1}{101.3}$ (1)

$P = 101.3 kPa$

$R = 8.315 J mol^{-1} K^{-1}$

$= 5.56 L$ (1)

$M(CO_2) = 44.01 g mol^{-1}$

[3 marks]

END OF PART 2

PART 3 **(40 marks)**

Answer **ALL** questions in Part 3. The calculations are to be set out in detail in this Question/Answer Booklet. Marks will be allocated for correct working, correct equations and clear setting out, even if you cannot complete the problem. Note that if an incomplete answer is given only partial marks will be awarded.
When questions are divided into sections, clearly distinguish each section using (a), (b), and so on. Express your final numerical answers to three (3) significant figures where appropriate, and provide units where applicable. Information which may be necessary for solving the problems is located on the separate Chemistry Data Sheet.

Question 35.

A 3.00 g sample of crude zinc sulfide ore containing sand and clay as impurities was roasted completely in air, according to the reaction below.

$$ZnS_{(s)} + O_{2\,(g)} \rightarrow Zn_{(s)} + SO_{2\,(g)}$$ reaction 1

The sulfur dioxide evolved was passed into 0.300 mol L^{-1} potassium dichromate solution. It was found that 31.9 mL of the potassium dichromate solution was required to react completely with the gas evolved.

$$Cr_2O_7^{2-}{}_{(aq)} + 2H^+{}_{(aq)} + 3SO_{2\,(g)} \rightarrow 2Cr^{3+}{}_{(aq)} + H_2O_{(l)} + 3SO_4^{2-}{}_{(aq)}$$ reaction 2

Calculate the percentage by mass of pure zinc sulfide in the crude ore.

[7 marks]

$V(K_2Cr_2O_7) = 31.9\,mL = 3.19 \times 10^{-2}\,L$

$c(K_2Cr_2O_7) = 0.300\,M$ $\quad n(K_2Cr_2O_7) = c.V$

$= 0.300 \times 3.19 \times 10^{-2}$

$= 9.57 \times 10^{-3}\,mol$

in solution $n(Cr_2O_7^{2-}) = n(K_2Cr_2O_7) = 9.57 \times 10^{-3}\,mol$

for reaction 2:

$n(SO_2) = \frac{3}{1} . n(Cr_2O_7^{2-}) = \frac{3}{1} \times 9.57 \times 10^{-3}$

$= 2.87 \times 10^{-2}\,mol$

for reaction 1:

$n(ZnS) = \frac{1}{1} . n(SO_2) = \frac{1}{1} \times 2.87 \times 10^{-2}$

$= \underline{2.87 \times 10^{-2} \text{ mol}}$

$M(ZnS) = M(Zn) + M(S)$
$= 65.38 + 32.06$
$= \underline{97.44 \text{ gmol}^{-1}}$

$m(ZnS) = n.M = 2.87 \times 10^{-2} \times 97.44$
$= \underline{2.80g}$

$m(\text{impure ZnS}) = 3.00g$

$\% \text{ purity} = \frac{m(\text{pure ZnS})}{m(\text{impure ZnS})} \times 100$

$= \frac{2.80}{3.00} \times 100$

$= \underline{93.3\%}$

Question 36.

In a laboratory experiment, a student prepared insoluble aluminium carbonate $Al_2(CO_3)_3$ by a precipitation reaction. She added 250.0 mL of 1.00 mol L^{-1} aluminium nitrate solution to 500.0 mL of 0.500 mol L^{-1} sodium carbonate solution.

(a) Write a balanced ionic equation for the precipitation reaction.

[1 marks]

(b) Determine the limiting reagent in this experiment.

[6 marks]

(c) Calculate the mass of aluminium carbonate precipitated.

[3 marks]

(d) What would be the concentration of the excess reagent in mol L^{-1} in the **final solution**?

[3 marks]

a) $2Al^{3+}_{(aq)} + 3CO_3^{2-}{}_{(aq)} \longrightarrow Al_2(CO_3)_{3\,(s)}$

b) $c(Al(NO_3)_3) = 1.00M$

$V(Al(NO_3)_3) = 250.0 mL$

$= 2.50\times10^{-1} L$

$n(Al^{3+}) = n(Al(NO_3)_3) = c.V$

$= 1.00 \times 2.50\times10^{-1}$

$= 2.50\times10^{-1}$ mol

$c(Na_2CO_3) = 0.50M$

$V(Na_2CO_3) = 500.0 mL$

$= 5.00\times10^{-1} L$

$n(CO_3^{2-}) = n(Na_2CO_3) = c.V$

$= 0.50 \times 5.00\times10^{-1}$

$= 2.50\times10^{-1}$ mol

Stoic. Ratio $= \dfrac{n(Al^{3+})}{n(CO_3^{2-})} = \dfrac{2}{3} = 0.667$

Actual Ratio $= \dfrac{n(Al^{3+})}{n(CO_3^{2-})} = \dfrac{2.50\times10^{-1}}{2.50\times10^{-1}} = 1.000$

As S.R. < A.R. limiting reagent is CO_3^{2-}

excess reagent is Al^{3+}

for ratio other way $\dfrac{n(CO_3^{2-})}{n(Al^{3+})}$

S.R = 1.50

A.R = 1.00

S.R > A.R.

L.R = CO_3^{2-}

E.R. = Al^{3+}

c) $M(Al_2(CO_3)_3) = 2 \times M(Al) + 3 \times M(C) + 9 \times M(O)$

$= (2 \times 26.98) + (3 \times 12.01) + (9 \times 16.00)$

$= \underline{233.99 \text{ g mol}^{-1}}$

$n(Al_2(CO_3)_3 = \frac{1}{3} \cdot n(CO_3^{2-}) = \frac{1}{3} \times 2.50 \times 10^{-1}$

$= \underline{8.33 \times 10^{-2} \text{ mol}}$

$m(Al_2(CO_3)_3) = nM = 8.33 \times 10^{-2} \times 233.99$

$= \underline{19.5 g}$

d) $n(Al^{3+})_{\text{consumed}} = \frac{2}{3} \cdot n(CO_3^{2-}) = \frac{2}{3} \times 2.50 \times 10^{-1}$

$= \underline{1.67 \times 10^{-1} \text{ mol}}$

$n(Al^{3+})_{\text{remaining}} = n(Al^{3+})_{\text{initial}} - n(Al^{3+})_{\text{consumed}}$

$= 2.50 \times 10^{-1} - 1.67 \times 10^{-1}$

$= \underline{8.33 \times 10^{-2} \text{ mol}}$

$V(\text{final}) = 0.250 L + 0.500 L)$

$= 0.750 L$

$c(Al^{3+})_{\text{remaining}} = \frac{n}{V} = \frac{8.33 \times 10^{-2}}{0.750}$

$= \underline{0.111 M}$

Question 37.

The production of the fertiliser, di-ammonium hydrogen phosphate, $(NH_4)_2HPO_4$, from rock phosphate (impure calcium phosphate), can be represented by the following reaction sequence.

Step 1

$$Ca_3(PO_4)_{2\,(s)} + 3H_2SO_{4\,(aq)} \rightarrow 2H_3PO_{4\,(aq)} + 3CaSO_{4\,(s)}$$

Step 2

$$H_3PO_{4\,(aq)} + 2NH_{3\,(g)} \rightarrow (NH_4)_2HPO_{4\,(s)}$$

(a) What mass of rock phosphate would be required to produce 1.00 tonne (1000 kg) of di-ammonium hydrogen phosphate if the rock phosphate contains 70.0 % by mass calcium phosphate? You may assume that the impurities in the rock phosphate do not react with the sulfuric acid or take part in the reaction.

[7 marks]

(b) What volume of ammonia gas measured at STP would be needed to bring about the above conversion?

[3 marks]

a) $m((NH_4)_2HPO_4) = 1000\text{ kg}$

$= 1.00 \times 10^6\text{ g}$

$M((NH_4)_2HPO_4) = 2\times M(N) + 9\times M(H) + 1\times M(P) + 4\times M(O)$

$= (2\times 14.01) + (9\times 1.008) + (1\times 30.97) + (4\times 16.00)$

$= 132.062\text{ g mol}^{-1}$

$n((NH_4)_2HPO_4) = \frac{m}{M} = \frac{1.00\times 10^6}{132.062} = 7.57\times 10^3\text{ mol}$

for Step 2:

$n(H_3PO_4) = \frac{1}{1} . n((NH_4)_2HPO_4) = \frac{1}{1} . 7.57\times 10^3$

$= 7.57\times 10^3\text{ mol}$

for step 1:

$n(Ca_3(PO_4)_2) = \frac{1}{2} \cdot n(H_3PO_4) = \frac{1}{2} \times 7.57 \times 10^3$

$= 3.79 \times 10^3\ mol$

$M(Ca_3(PO_4)_2) = 3 \times M(Ca) + 2 \times M(P) + 8 \times M(O)$

$= (3 \times 40.08) + (2 \times 30.97) + (8 \times 16.00)$

$= 310.18\ g\,mol^{-1}$

$m(Ca_3(PO_4)_2)$ pure $= n.M = 3.79 \times 10^3 \times 310.18$

$= 1.17 \times 10^6\ g$

purity of rock phosphate $= 70.0\%$

$\%\ purity = \frac{m(pure\ Ca_3(PO_4)_2)}{m(impure\ Ca_3(PO_4)_2)} \times 100$

$\therefore M(\text{impure rock phosphate}) = \frac{m(pure\ Ca_3(PO_4)_2)}{\%\ purity} \times 100$

$= \frac{1.17 \times 10^6}{70.0} \times 100$

$= 1.68 \times 10^6\ g = 1.68$ tonnes

b) at STP

$P = 101.3\ kPa$

$T = 273.1\ K$

$R = 8.315\ J K^{-1} mol^{-1}$

$n(NH_3) = \frac{2}{1} \times n((NH_4)_2HPO_4)$

$= \frac{2}{1} \times 7.57 \times 10^3 = 1.51 \times 10^4\ mol$

$PV = nRT$

$\therefore V(NH_3) = \frac{nRT}{P} = \frac{1.51 \times 10^4 \times 8.315 \times 273.1}{101.3}$

$= 3.38 \times 10^5\ L$

Question 38.

"An understanding of the three dimensional structure of a covalent molecule enables its polarity and intermolecular forces to be predicted."

Expand on this statement by discussing the following topics;

(a) Valence electron pair repulsion theory.
(b) Shapes of molecules.
(c) Molecular polarity.
(d) Intermolecular forces.

The following table of data for some commonly known covalent molecular substances may be useful for in answering your question. Your answer could also include any other appropriate molecules as examples.

Substance	Boiling point
methane	-162 °C
water	100 °C
carbon dioxide	- 78 °C (sublimes)
ammonia	- 33 °C

Marks are awarded principally for the relevant chemical content of your answer, but some marks can also be gained for clarity in arranging a reasonable amount of material in a coherent form. It is suggested that you write between 1½ and 2 pages to answer the question.

[10 marks]

Discuss:

i) VSEPR - electron groups around central atom
- repulsion gives base shape
- possible shapes
- examples CH_4 - tetrahedral
H_2O - U shaped / bent
CO_2 - linear
NH_3 - trigonal pyramidal

ii) Molecular polarity — electronegativity and electron sharing forming polar bonds.

- net dipole of polar bonds and shape

- examples CH_4 - non-polar

H_2O - very polar

CO_2 - non-polar

NH_3 - very polar

iii) Intermolecular forces - Types and defn

↳ dispersion, dipole-dipole, H-bonding

- Influence on strength of intermolecular bonds and physical properties (B.P)

- examples

strength of Intermolecular forces

$H_2O > NH_3 > CO_2 > CH_4$

ranks B.P order.

marks for general structure/orders etc