PART 1 (60 marks = 30% of paper)

Answer ALL questions in Part 1 on the separate Multiple Choice Answer Sheet provided. Each question in this part is worth 2 marks.

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1. Raising the temperature of the system:

$$N_{2(g)} + 3\,H_{2(g)} \rightleftarrows 2\,NH_{3(g)} + 45kJ$$

A. increases the rate of ammonia formation and has no effect on the yield of ammonia in the equilibrium mixture

B. increases the rate of ammonia formation and decreases the yield of ammonia in the equilibrium mixture

C. increases the rate of ammonia formation and increases the yield of ammonia in the equilibrium mixture

D. decreases the rate of ammonia formation and decreases the yield of ammonia in the equilibrium mixture

2. Which of the following statements concerning rubidium, Rb, in group 1 is false?

A. It has a lower melting point than sodium

B. Its first ionisation energy is larger than that of potassium

C. It forms an ionic hydride

D. It will react with cold water violently

3. Which set of examples below of the different classes of solid is correct?

	Ionic	Polar molecular	Non-polar molecular	Covalent network	Metallic
A.	KI	C_6H_5Cl	I_2	SiC	Ba
B.	Na_2S	SO_2	SO_3	GaAs	Si
C.	H_2SO_4	H_2SO_3	CBr_4	SiO_2	V
D.	BaO	CS_2	CH_4	Si	Pb

4. Which of the following trends in first ionisation energy is not correct?

   A. Pb < Sn < Si < C

   B. K < Ca < Ge < As

   C. Te < Se < S < O

   D. F < P < Al < Sr

5. The equilibrium constant, K, of the reaction:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2\,HI_{(g)}$$

   is 66.5 at 633 K and 50.7 at 713 K. Which statement is false?

   A. At equilibrium no $HI_{(g)}$ is being produced since all concentrations are constant

   B. The forward reaction is exothermic

   C. $K = [HI]^2/[H_2][I_2]$

   D. An increase in pressure will have no resultant shift of equilibrium

6. The potential energy of the products in the reaction:

$$N_{2(g)} + O_{2(g)} \rightleftarrows 2\,NO_{(g)}$$

   is greater than the potential energy of the reactants. If the temperature of above system, at equilibrium, were increased the mass of NO would:

   A. increase and the K value would increase

   B. increase and the K value would decrease

   C. decrease and the K value would increase

   D. decrease and the K value would decrease

7. Which of the following has the lowest boiling point?

   A. HBr

   B. HI

   C. HCl

   D. HF

8. The table below gives four consecutive ionisation energies (in MJ mol^{-1}) of element X.

1^{st}	2^{nd}	3^{rd}	4^{th}
1.5	7.7	8.6	9.8

It may therefore be deduced that X is:

A. Li

B. Ca

C. K

D. Mg

9. Which of the following would not change the initial rate of reaction between zinc and 1 mol L^{-1} nitric acid?

A. The addition of a catalyst

B. A change of in the temperature of the reactants

C. Use double the volume of nitric acid solution

D. Breaking down the zinc into smaller pieces

10. Which of the following best describes the molecular shape and molecular polarity respectively of an H_2S molecule?

A. linear and non-polar

B. linear and polar

C. bent and non-polar

D. bent and polar

11. The amount of arsenic in a pesticide may be determined by precipitation of the arsenic as its sulfide, As_2S_3. If 0.246 g of As_2S_3 is obtained from 1.50 g of pesticide, the percentage by mass of As in the pesticide is:

A. 0.5%

B. 1.0%

C. 5.0%

D. 10.0%

12. An element X forms molecules with the formula NX_3 when combined with the element nitrogen. The electronic configuration of neutral atoms of element X could be:

A. $1s^2 2s^2 2p^2$

B. $1s^2 2s^2 2p^5$

C. $1s^2 2s^2 2p^3$

D. $1s^2 2s^2 2p^6 3s^1$

13. The number of orbitals that exist in the 4^{th} electron shell is:

A. 4

B. 8

C. 16

D. 12

14. Which of the following species has an equal number of protons and neutrons and also contains six less neutrons that a ^{39}K atom?

A. ^{26}Al

B. ^{28}Si

C. ^{30}P

D. ^{32}S

15. Three samples of a white crystalline substance were analysed.

Sample 1 2.00 g taken from sea water was found to have 0.780 g of sodium, the rest chlorine

Sample 2 found in the kitchen; had 61% chlorine by mass, the rest sodium

Sample 3 3.00 g found in an underground deposit had 1.83 g of chlorine and 1.17 g sodium

We can conclude that:

A. all three were probably the same compound since all three contained sodium and chlorine
B. the three sample were different compounds as they all come from quite different areas
C. all three were probably the same compound as all have sodium and chlorine in the same proportions by mass
D. the three samples were different compounds as the sodium and chlorine were present in different proportions

16. Methanol is made from $CO_{(g)}$ and $H_{2(g)}$ as follows:

$$CO_{(g)} + H_{2(g)} \rightleftarrows CH_3OH_{(g)} + 93\ kJ$$

Which of the following changes, once equilibrium had been re-established, would increase the rate of formation of methanol.

I raising the temperature

II reducing the volume of the container

III adding more CO

IV adding methanol to the container

A. II and III only

B. I, II and III only

C. I, II and IV only

D. all of them

17. CCl_4 and CH_4 are structurally similar yet CCl_4 is a liquid at room temperature and CH_4 is a gas at room temperature. This is because:

A. methane molecules can form hydrogen bond

B. tetrachloromethane has stronger dispersion forces

C. chlorine is more electronegative than hydrogen

D. tetrachloromethane has stronger dipole-dipole forces

18. Of the following compounds, which would you expect to have the highest solubility in water?

A. CH_3CH_2CHO

B. $HCOOCH_3$

C. $CH_2CH_2CH_2OH$

D. $CH_3CH_2CH_2CH_3$

19. Paraffin wax is a mixture of high molecular mass alkanes which is often used as a water-proofing agent because of its water repellent properties and its insolubility in water. It is applied to fabrics by soaking them in a solution of paraffin wax dissolved in the solvent "Shellite".

From this information, it is reasonable to infer that "Shellite":

A. is soluble in water

B. has a higher relative molecular mass than water

C. forms weaker bonds to paraffin wax molecules than to "Shellite" molecules

D. is a non-polar solvent

20. Which two combinations of elements X and Y given below would be most likely to form an ionic bond?

A. X has electron configuration $1s^2 2s^1$ and Y has electron configuration $1s^2 2s^2 2p^6$

B. X has one electron in its 3d sub-shell and Y has a valence electron configuration of s^2

C. X is period 4, group 1 and Y is in period 1

D. X is shiny and conducts electricity in both solid and liquid states and Y has electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6$

21. Consider the following equilibrium system established in sealed container:

$$MgSO_{3(s)} + \text{heat} \rightleftarrows SO_{2(g)} + MgO_{(s)}$$

Which of the following changes would increase the yield (mass) of SO_2?

I decreasing the temperature
II decreasing the volume of the reaction vessel
III adding more $MgSO_{3(s)}$

A. I only
B. II only
C. III only
D. None of them

22. A compound of mass 1.00 g is obtained when 0.720 g of Mg is reacted with nitrogen gas. The empirical formula of the compound is:

A. Mg_3N_2

B. MgN

C. Mg_2N_3

D. MgN_2

23. 0.200 g of gas X occupies a volume of 440 mL. If 0.100 g of $CO_{2(g)}$ occupies a volume of 320 mL at the same temperature and pressure, gas X could be:

A. O_2

B. NO

C. SO_2

D. C_4H_{10}

24. In which one of the following reactions would a visible reaction occur?

A. a piece of $K_{(s)}$ is added to ethanol

B. acidified potassium permanganate is added to propanone

C. methanol is added to warm ethanoic acid in presence of concentrated sulphuric acid

D. acidified potassium dichromate is added to 2-methyl-2-butanol

25. Which of these molecules are planar and non-polar?

I methanal

II benzene

III ethene

IV propene

V methylbenzene

A. I, II, III and V

B. II, III and IV

C. II and III only

D. II and V only

26. Which of these chemicals would be best to use so as to distinguish between ethanoic acid and methyl-2-propanol?

A. sodium, Na

B. acidified $MnO_4^-{}_{(aq)}$

C. sodium hydrogencarbonate, $NaHCO_3$

D. red litmus paper

27. Which of the following compounds can form geometric isomers?

A. 1-butene

B. 1-pentene

C. 2-methyl-2-butene

D. 2-pentene

28. Which of the following pairs of chemicals, in the presence of concentrated sulfuric acid, could be used to make the compound whose structure is below?

$CH_3CH(CH_3)CH_2COOCH_2CH(CH_3)CH_3$

A. 2-methyl-butanoic acid and methyl-1-propanol

B. 3-methyl-1-butanol and methyl-propanoic acid

C. 3-methyl-butanoic acid and methyl-1-propanol

D. 3-methyl-butanoic acid and methyl-2-propanol

29. Which of the following may be used to produce a condensation polymer?

A. $HOOCCH_2CH_2CH_2COOH$

B. $HOCH_2CH_2CH_2OH$ and $CH_3CH_2CH_2COOH$

C. $HOCH_2CH_2CH_3$ and $CH_3CH_2CH_2COOH$

D. $HOCH_2CH_2CH_2CH_2OH$ and $HOOCCH_2CH_2CH_2COOH$

30. The empirical formula of ethylbenzene is:

A. C_8H_{10}

B. C_8H_{11}

C. C_4H_5

D. C_4H_7

END OF PART 1

PART 2 (70 marks = 35% of paper)

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

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1. Write equations for any reactions that occur in the following procedures. If no reaction occurs, write 'no reaction'.

   In each case describe in full what you would observe, including any: colours; odours; precipitates (give the colour); or gases evolved (give the colour or describe as colourless). If a reaction occurs but the change is not visible, then you should state this.

(a) Solid potassium carbonate is added to excess nitric acid.

Equation _____

Observation _____

_____

(b) Dilute sulfuric acid is added to barium chloride solution.

Equation _____

Observation _____

_____

(c) Nickel(II) oxide is added to ethanoic acid.

Equation _____

Observation _____

_____

(d) A piece of sodium is added to ethanal.

Equation _____

Observation _____

_____

(12 marks)

2. For each species listed in the table below draw the structural formula, representing all valence shell electron pairs either as : or –. Also identify the molecular shape and polarity.

Species	*Structural formula*	*Shape*	*Polarity*
N_2O (NNO)			
ONCl			
$AsCl_3$			

(12 marks)

3. Identify the most important forces of attraction in determining the melting point of the following solids:

(a) NH_4Cl _____

(b) SO_3 _____

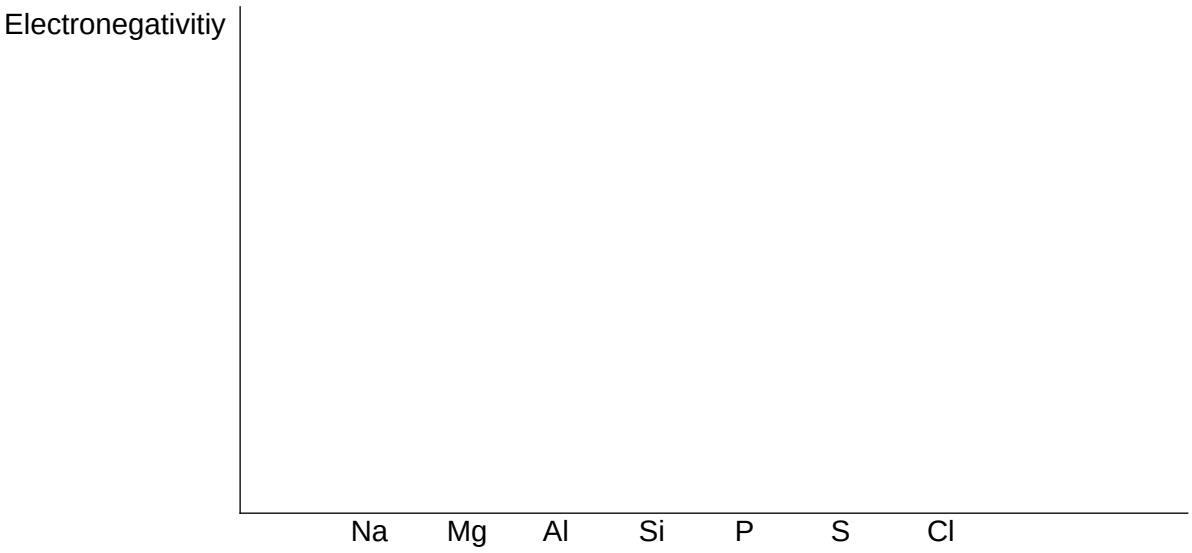
(c) CH_3NH_2 _____

(d) SiC _____

(4 marks)

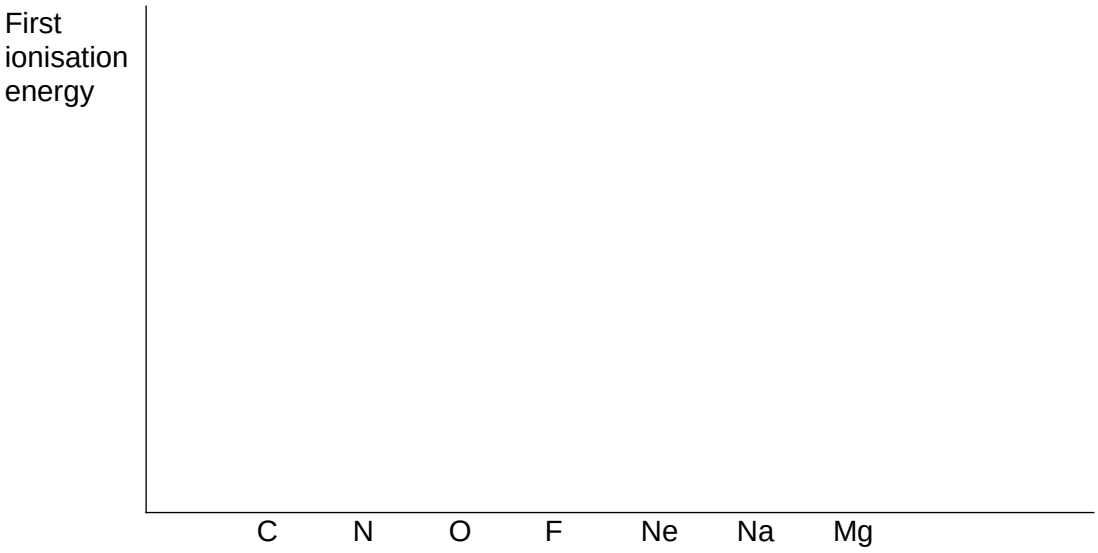
4. Sketch graphs that depict the following trends:

(a) Electronegativity of the period 3 elements



(1 mark)

(b) First ionisation energies of elements carbon to magnesium.



(2 marks)

5. Account for the trend in solubility in water for the following alcohols:

Alcohol	*Solubility (g/100g water at 20ºC)*
methanol	miscible in all proportions
ethanol	miscible in all proportions
1-propanol	miscible in all proportions
1-butanol	8.14
1-pentanol	2.64
1-hexanol	0.59
1-heptanol	0.09

(4 marks)

6. (a) Use the numbers 1 to 6 to rank the following molecules from highest boiling point (1) to lowest boiling point (6)

Name	*Molar mass ($g\ mol^{-1}$)*	*Rank*
butane, $CH_3CH_2CH_2CH_3$	58.1	
ethanoic acid, CH_3COOH	60.1	
methylpropane, $CH_3CH(CH_3)CH_3$	58.1	
propanal, CH_3CH_2CHO	58.1	
1-propanol, $CH_3CH_2CH_2OH$	60.1	
2-propanol, $CH_3CH(OH)CH_3$	60.1	

(3 marks)

(b) Account for the difference in boiling point between propanal and 1-propanol.

(3 marks)

7. Consider the following information:

Compound **A**, a colourless liquid with formula C_3H_8O, reacts with concentrated phosphoric acid to give compound **B**, with formula C_3H_6, which rapidly discolours a solution of bromine water.

When a piece of sodium is added to compound **A** an odourless, colourless gas evolves.

When compound **A** is treated with concentrated ethanoic acid compound **C**, a sweet smelling liquid with formula $C_5H_{10}O_2$, is formed.

When compound **A** is completely oxidised by reaction with acidified potassium dichromate compound **D**, with formula C_3H_6O, is formed.

When a piece of sodium is added to compound **D**, there is no visible reaction.

(a) Draw structural formula and give IUPAC names for the following:

Compound	*Structural formula*	*IUPAC name*
A		
B		
C		
D		

(8 marks)

(b) (i) Write an equation for the reaction of compound **A** with sodium.

_____

(ii) Name the organic product of the reaction.

_____

(3 marks)

(c) (i) Write an equation for the reaction of compound **B** with a solution of bromine water.

_____

(ii) Name the product of the reaction.

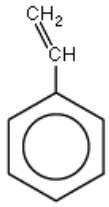
_____

(iii) Name and sketch an isomer of compound **B**, which would not rapidly discolour a solution of bromine water.

_____ _____

(5 marks)

8. The structure of styrene is:



(a) Name type of polymer that styrene will form.

_____

(1 mark)

(b) Sketch a section of polystyrene with at least three monomer units.

(2 marks)

9. Ammonium carbamate (NH_4OCONH_2) decomposes forming ammonia and carbon dioxide, according to the following equilibrium:

$$NH_4OCONH_{2(s)} \rightleftarrows 2\ NH_{3(g)} + CO_{2(g)} \qquad \Delta H = -450\ kJ\ mol^{-1}$$

(a) Write an expression for the equilibrium constant, K.

(1 mark)

(b) Three vessels contain an equilibrium mixture of this system, each of which is subjected to one of the changes described below. In each case, describe the effect of the change on the following once equilibrium has been re-established:

- the rate of the forward reaction (increase, decrease, no change)
- the mass of CO_2 (increase, decrease, no change)
- the value of the equilibrium constant, K (increase, decrease, no change)

Vessel	*Change*	*Forward reaction rate*	*Mass of CO_2*	*Value of K*
1	Increase in temperature			
2	Addition of neon gas at constant volume			
3	Increase in volume at constant temperature			

(9 marks)

END OF PART 2

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PART 3 (50 marks = 25% of paper)

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 equations and clear setting out, even if you cannot complete the problem. 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 that may be necessary for solving the problems is located on the separate Chemistry Data Sheet. Show clear reasoning: if you do not, you will lose marks.

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1. An experiment was carried out to determine the amount of calcium carbonate present in a sample of an antacid tablet. A 1.42 g tablet was crushed and then reacted with an excess of 0.200 mol L^{-1} hydrochloric acid. The resulting solution was filtered and the filtrate washed through with distilled water. An excess of oxalic acid solution was added to the filtrate, resulting in the formation of a precipitate of calcium oxalate (CaC_2O_4). When dried, this precipitate had a mass of 0.937 g.

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

   (b) Calculate the percentage by mass of calcium carbonate in the tablet.

   (c) Calculate the minimum volume of hydrochloric acid required to completely react with the calcium carbonate in the first stage of the process.

   (2 + 4 + 2 = 8 marks)

2. Each year, millions of tonnes of iron ore, impure iron (III) oxide, are mined. This ore is converted to iron in the blast furnace. The overall reaction which leads to the production of iron in the blast furnace is given by the following equation:

$$Fe_2O_{3(s)} + 3\ CO_{(g)} \rightarrow 2\ Fe_{(l)} + 3\ CO_{2(g)}$$

In a blast furnace, 25 tonnes of iron ore (containing 87% Fe_2O_3) and 1.53×10^7 L of carbon monoxide are reacted together at 110 kPa and 750 K.

(a) Determine the limiting reactant?

(b) Calculate the mass of iron that could be produced in the reaction?

(5 + 2 = 7 marks)

3. A student was given an acid mixture which contained sulfuric acid and nitric acid. The following steps were carried out to determine the concentration of each acid present in the mixture.

I A 25.0 mL sample of the acid mixture was reacted with a 0.150 mol L^{-1} solution of sodium hydroxide. The volume of sodium hydroxide required for complete neutralisation of the acids present was 92.0 mL.

II To a 50.0 mL sample of the acid mixture excess barium chloride solution was added. The precipitate formed was collected, dried and weighed. It was found to have a mass of 1.56 g.

(a) Write an ionic equation to represent the reaction carried out in step **I**.

(b) Determine the hydrogen ion concentration of the acid mixture.
(You may assume that the sulfuric acid is completely ionised)

(c) Write an ionic equation to represent the reaction in step **II**.

(d) Calculate the sulfuric acid concentration.

(e) Calculate the nitric acid concentration.

(1, 3, 1, 3, 2 = 10 marks)

4. The main source of the metal manganese is from the ore pyrolusite, which contains manganese (IV) oxide, MnO_2. It is converted into manganese by the following two reactions.

$$3\ MnO_2 \rightarrow Mn_3O_4 + O_2$$

$$3\ Mn_3O_4 + 8\ Al \rightarrow 4\ Al_2O_3 + 9\ Mn$$

Given that a 2.00 tonne sample of pyrolusite contained 73.0% MnO_2 and that the efficiencies of the two reactions are 83.0% and 94.0% respectively, calculate:

(a) the maximum mass of Mn that could be extracted.

(b) the volume of oxygen gas given off in the first reaction, measured at 500^0C and 105 kPa.

(c) the minimum mass of Al that would be needed in the second reaction.

(6 + 3 + 3 = 12 marks)

5. Amino acids contain one or more amine groups and one or more carboxylic acid groups. The diprotic amino acid, glutamic acid, which contains carbon, hydrogen, nitrogen and oxygen only, underwent analysis to determine its formula.

When a 5.00 g sample of glutamic acid was completely combusted in oxygen, 7.48 g of carbon dioxide and 2.77 g of water was produced.

A separate 3.00 g sample produced 0.938 g of nitrogen dioxide when burnt in oxygen.

Finally, 4.56 g of glutamic acid was dissolved in 100.0 mL of distilled water. A 20.0 mL sample of this solution required 24.8 mL of 0.500 mol L^{-1} sodium hydroxide solution for complete neutralization.

(a) Calculate the empirical formula of glutamic acid.

(b) Calculate the molecular formula of glutamic acid.

(8 + 5 = 13 marks)

END OF PART 3

PART 4 (20 marks = 10% of paper)

Answer the following extended answer question. Where applicable use equations, diagrams and illustrative examples of the chemistry you are describing.

Marks are awarded for the relevant chemical content of your answer, but you will lose marks if what you write is unclear or lacks coherence.

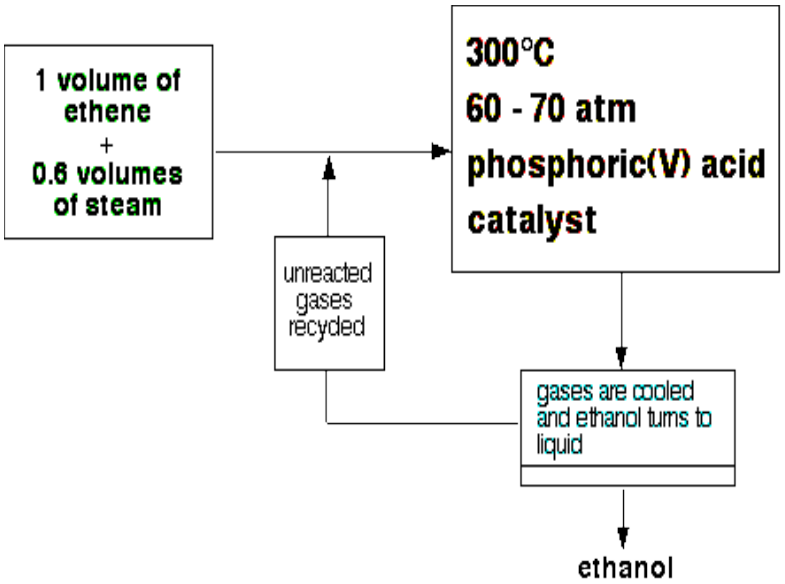
Vinegar is a widely used chemical and it is a 4 - 5% (by mass) solution of ethanoic acid, CH_3COOH. Ethanoic acid is made from the oxidation of ethanol and this is prepared from the hydration of ethene under special conditions. The reaction is reversible and exothermic.

$$CH_2{=}CH_{2(g)} + H_2O_{(g)} \rightleftarrows CH_3CH_2OH_{(g)} \quad \Delta H = -45 \text{ kJ mol}^{-1}$$

Below is a simple sketch that describes of the manufacture of ethanol from ethene and steam.

The temperature used is 300^{o}C with a pressure of 60 to 70 atm. The pressure is maintained at this level because at higher pressures the polymerisation of ethene cccurs.

Although steam is a very cheap reactant, the ratio to ethene to steam is 1 : 0.6 because too much steam interferes with the phosphoric acid catalyst.



Using your knowledge of rate of reaction and equilibrium principles, discuss the production of ethanol from ethene and steam. State reasons for the conditions used as outlined shown in flow chart above.

Also discuss, with equations where applicable, the physical and chemical properties of ethanol.

END OF EXAMINATION