Year 12 Chemistry Mid Year Examination 2011

Section One: Multiple-choice **25% (50 Marks)**

This section has **25** questions. Answer **all** questions on the Multiple-choice Answer Sheet provided. Use only blue or black pen to shade the boxes. If you make a mistake, place a cross through that square. Do not erase or use correction fluid. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is given for any question.

Suggested working time: 50 minutes.

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1. D

2. B

3. B

4. C

5. C

6. B

7. C

8. D

9. B

10. C

11. A

12. B

13. C

14. A

15. C

16. B

17. A

18. D

19. A

20. D

21. B

22. D

23. D

24. C

25. B

Section Two: Short Answer **35% (70 Marks)**

Question 26 **(10 marks)**

Consider the following system:

$CO(g) + 2\ H_2(g) \rightleftarrows CH_3OH(g)$ $K = 2.34 \times 10^{-1}$ at 25°C

(a) If at 58°C, $K = 4.56 \times 10^{-2}$ (4 marks)

Is this reaction exothermic or endothermic? **Exothermic** ✓

Explain your answer:

As temperature increases, K has decreased ✓

which means less products, therefore equilibrium has shifted LEFT. ✓

Since temperature increase favours an endothermic reaction, the reverse is endothermic, therefore the forward is exothermic. ✓

(b) Predict whether the following changes will increase, decrease or have no effect on both the rate and the equilibrium yield. (6 marks)

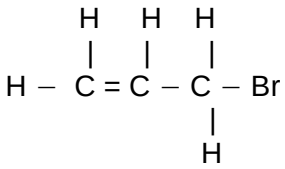
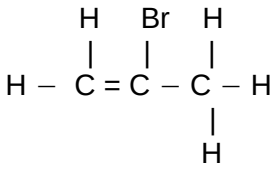
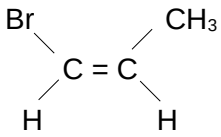
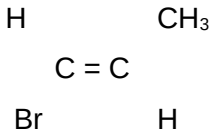
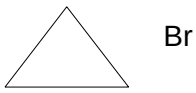
Change	Effect on rate	Effect on yield
Increasing the pressure of the system	**increase**	**increase**
Adding a catalyst	**increase**	**No change**
Decreasing the temperature	**decrease**	**Increase ****

** decrease if (a) is given as endothermic

✓ **each**

Question 27 **(10 marks)**

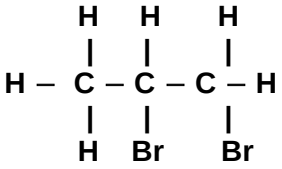
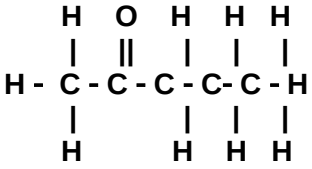
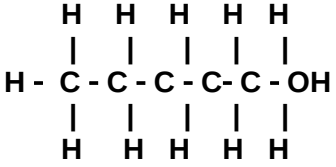
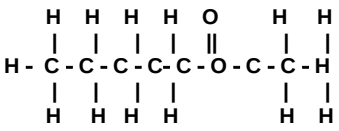
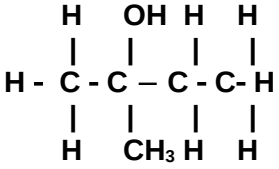
Give the names and the structures of all the isomers of C_3H_5Br.

Structures	IUPAC names
	**3 – bromopropene**
	**2 – bromopropene**
	**cis-1-bromopropene**
	**trans-1-bromopropene**
	**bromocyclopropane**

✓ **each**

Question 28 **(10 marks)**

Draw structural formulae and give the IUPAC name for the organic compounds which match the descriptions in (a) to (e). Show all atoms in the structural formulae.

Description	Structure	IUPAC Name
(a) The product of the reaction between propene and bromine solution		**1,2-dibromopropane**
(b) The organic product formed when the alcohol, pentan-2-ol, is oxidised with acidified potassium permanganate solution.		**2-pentanone**
(c) An isomer of pentan-2-ol that can react with excess potassium permanganate solution to form pentanoic acid.		**1- pentanol**
(d) The pentanoic acid formed in (c) is then mixed with ethanol, a few drops of concentrated sulfuric acid are added and the mixture is warmed		**ethylpentanoate**
(e) Give structure and name of an isomer of pentan-2-ol that will not react with the potassium permanganate solution.		**2-methyl-2-butanol**

✓ each

-1 for missing hydrogen atoms

Question 29 (4 marks)

Write the equation for the reaction that occurs in each of the following procedures. If no reaction occurs, write 'no reaction'. For full marks, chemical equations should refer only to those species consumed in the reaction and the new species produced. These species may be ions [for example $Ag^+(aq)$], molecules [for example $NH_3(g)$, $NH_3(aq)$, $CH_3COOH(l)$] or solids [for example $BaSO_4(s)$, $Cu(s)$, $Na_2CO_3(s)$].

(a) Sodium hydrogencarbonate solution is mixed with hydrochloric acid solution. (2 marks)

Equation: **$HCO_3^-(aq) + H^+(aq) \rightarrow CO_2(g) + H_2O(l)$** ✓✓

(b) Barium nitrate solution is mixed with sulfuric acid solution. (2 marks)

Equation: **$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$** ✓✓

Question 30 (6 marks)

Write observations for any reactions that occur in the following procedures (a) and (b).
In each case describe in full what you would observe, including any

- colours
- odours
- precipitates (give the colour)
- gases evolved (give the colour or describe as colourless).

If no change is observed, you should state this.

(a) Excess hydrochloric acid is added to copper carbonate solid. (2 marks)

Observation: **Colourless solution is added to a green solid which dissolves to form a blue solution, colourless & odourless gas evolved.** ✓✓

(b) Excess iron (II) nitrate solution is mixed with sodium hydroxide solution. (2 marks)

Observation: **Pale green solution is added to a colourless solution. A pale green precipitate is formed and the solution remains pale green.** ✓✓

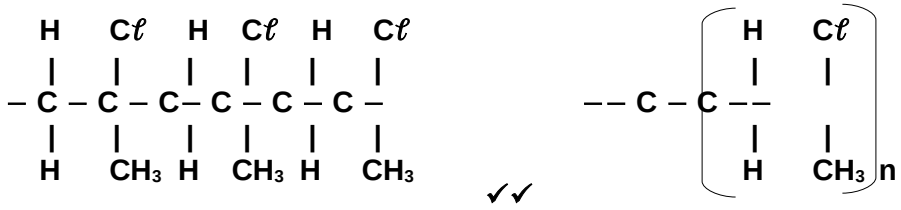
(c) Write full observations for this reaction: (2 marks)

$$Cu(s) + 4\ H^+(aq) + 2\ NO_3^-(aq) \rightarrow Cu^{2+}(aq) + 2\ H_2O(l) + 2\ NO_2(g)$$

Observation: **Salmon pink solid is added to a colorless solution. A blue solution forms and a pungent, brown gas is evolved.** ✓✓

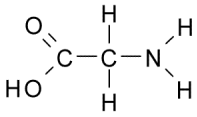
Question 31 **(6 marks)**

(a) Draw a piece of polymer formed from the monomer 2-chloropropene.
Show at least 3 monomer units. (2 marks)

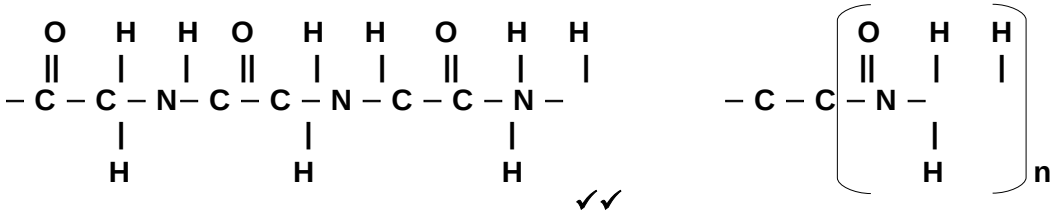


✓✓

(b) Draw a piece of polymer formed from the monomer glycine $H_2C(NH_2)COOH$;

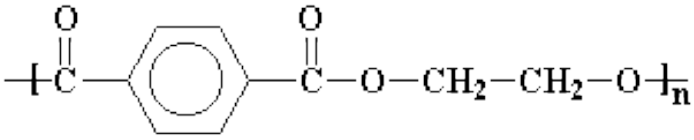


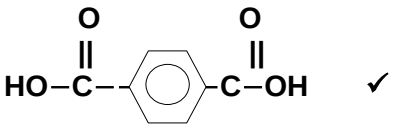
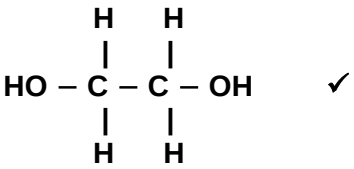
Show at least 3 monomer units. (2 marks)



✓✓

(c) Draw the structures of the two monomers that were used to make this polymer:
(2 marks)



Monomer 1	Monomer 2
 ✓	 ✓

Question 32 **(6 marks)**

For each species listed in the table below, draw the structural formula, representing all valence shell electron pairs either as **:** or as — **and** state or draw the shape of the molecule or ion.

Molecule or ion	Structural formula	Shape
H_2CO	**H** **|** **H - C = O |** ✓	**Triangular Planar** ✓
SO_3^{2-}	**| O - S - O |** **|** **|O|** **2-** ✓	**Pyramidal** ✓
CS_2	**|S = C = S |** ✓	**Linear** ✓

Question 33 **(6 marks)**

Using the information in the table below, identify the substances A to F from the following list:

aluminium	calcium carbonate	copper	copper (II) carbonate
octane	graphite	iodine	potassium chloride
nickel (II) chloride	silicon dioxide	mercury	

	Electrical conductivity in the solid state	Electrical conductivity in the liquid state	Solubility in water	Phase at 25°C	Colour at 25°C	Name of substance
A	nil	conducts	soluble	solids	white	**potassium chloride**
B	conducts	conducts	insoluble	solid	silver	**aluminium**
C	nil	nil	insoluble	liquid	colourless	**octane**
D	nil	nil	insoluble	solid	white	**silicon dioxide**
E	conducts	conducts	insoluble	liquid	silver	**mercury**
F	nil	n/a	insoluble	solid	green	**copper (II) carbonate**

✓ **each**

Question 34 **(5 marks)**

The diagram below shows the energy distribution curve for a gaseous reaction at 25°C. The activation energy for the uncatalysed reaction is also indicated. If the temperature is raised to 68°C, redraw the distribution curve. A catalyst was also added. Show on the diagram the catalyzed activation energy.

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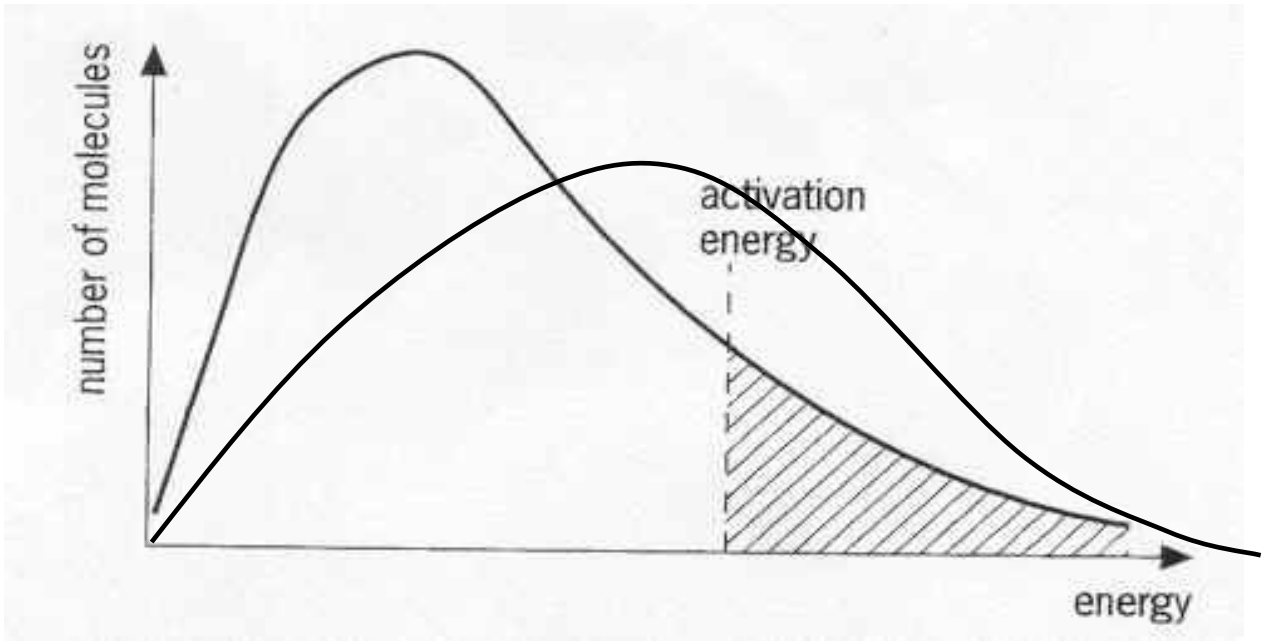


✓ **change in curve**

✓ **change in E_a**

Explain, using the above diagram, how the rate of reaction is affected with increased temperature and addition of a catalyst.

The rate will increase with temperature and with a catalyst. Using collision theory:

As the temperature is increased, the average kinetic energy of the molecules increases leading to an increase in velocity and hence the frequency of collisions increases, hence rate increases. ✓

At the higher temperature, the proportion of particles with energy greater that the minimum energy required for reaction (energy of activation) increases. ✓

A catalyst provides an alternative pathway for reaction, this pathway has a lower energy of activation and hence there are more particles with sufficient energy to collide and hence a greater chance of successful collisions thereby increasing rate. ✓

Question 35 **(4 marks)**

The melting points (°C) of the oxides of four consecutive elements of period 3 are as follows:

2852	2050	1725	300

Give the formula of the oxides with the melting points of 2852°C and 1725°C. (2 marks)

Melting point	Formula of oxide
2852°C	**MgO**
1725°C	**SiO_2**

✓✓

Give a brief explanation of your choices: (2 marks)

Going across period three the bonding types change from ionic to covalent network to covalent molecular.

The large decrease from 1725°C to 300°C indicates that the substance that melts at 300°C is first covalent molecular oxide - phosphorous ✓

Since they are consecutive, working backwards gives:

- **1725°C = SiO_2 (network – high melting point)**
- **2050°C = $A\ell_2O_3$ (ionic – high melting point)**
- **2852°C = MgO (ionic – high melting point)** ✓

Question 36 **(3 marks)**

Explain why the removal of a certain glue stuck on a desk was achieved by using ethanol but not petrol.

Ethanol is a polar solvent since the force of attraction between molecules is hydrogen bonding. ✓

Petrol is a mixture of hydrocarbons – these have only dispersion forces between molecular, making it a non-polar solvent. ✓

For the glue to be removed by ethanol implies that the glue is comprised of polar molecules. ✓

End of Section Two

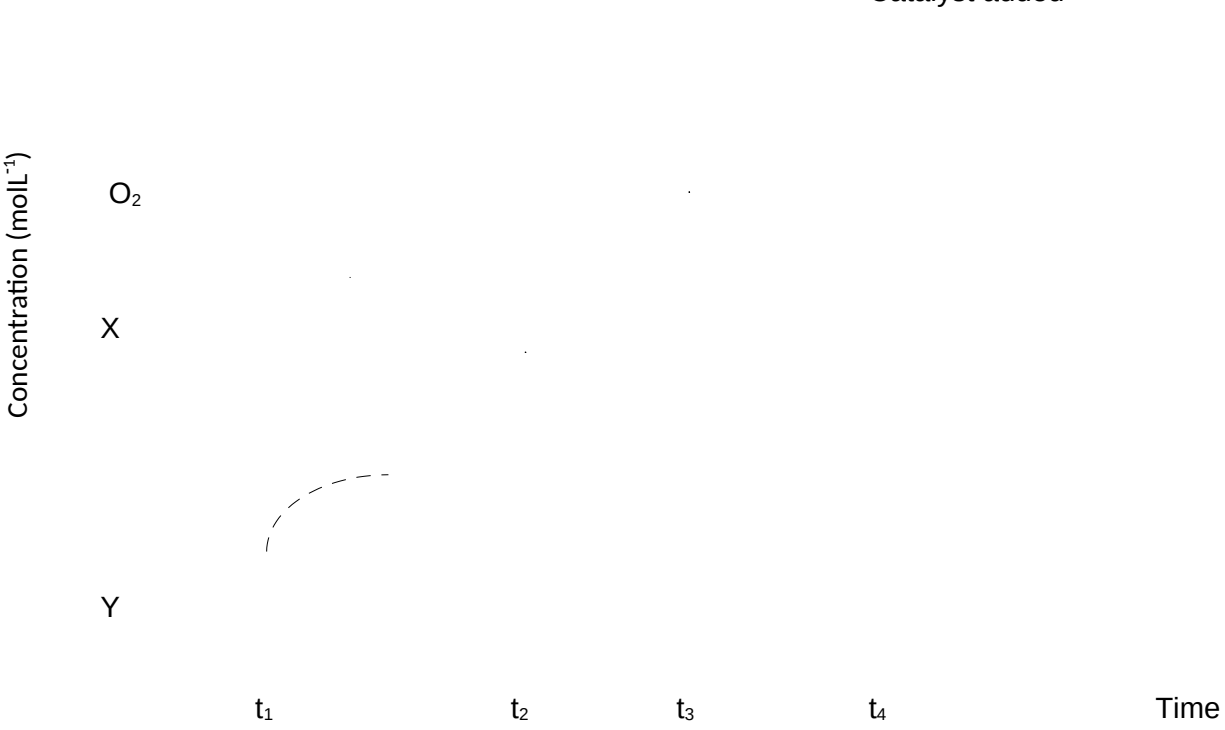
Section 3: Extended answer **40% (80 Marks)**

Question 37 **(22 marks)**

The second stage in the manufacture of sulphuric acid is the Contact Process, which involves the oxidation of sulphur dioxide into sulphur trioxide.

$$2\ SO_2(g) + O_2(g) \rightleftarrows 2\ SO_3(g) \quad \Delta H = -190\ kJ\ mol^{-1}$$

The above reaction is at equilibrium and some changes were made to the system. The graph below represents the changes made at t_1, t_2, and t_3. (The system re-establishes equilibrium before each new change is made)



(a) Based on the change that took place at t1 it follows that:

X = **SO_2** and Y = **SO_3** ✓ (1 mark)

State what change is likely to have occurred at: (3 marks)

t_1 **oxygen gas is added** ✓

t_2 **the volume is decrease** ✓

t_3 **the temperature is decreased** ✓

At t_4, a catalyst, vanadium pentoxide (V_2O_5), is added to the system. Continue the graphs to represent the changes in concentration of the three gases when a catalyst is added. (1 mark)

Graph to show that [ ] of all species remains constant ✓

(b) In the Contact Process, it is important to maximise both the yield of SO_3 and the rate of reaction. Use your knowledge of equilibrium and rates to predict and explain the optimum conditions of temperature and pressure for production of SO_3.
The equation for the Contact Process is repeated below:

$$2\ SO_2(g) + O_2(g) \rightleftarrows 2\ SO_3(g) \qquad \Delta H = -190\ kJmol^{-1}$$

(8 marks)

The rate of this chemical reaction will be increased by an increased in temperature, an increased in reactant concentration (pressure).

The temperature increases rate since it increases the frequency of collisions as well as their forcefulness, since it increases the proportion of particles with energy greater than the energy of activation. ✓ ✓

The increase in pressure leads to increased frequency of collisions and hence greater rate. ✓

The yield of sulfur trioxide will be increases by having a low temperature and a high pressure.

By LCP, a decrease in temperature will cause a shift in the direction of the exothermic reaction – in this case, the forward reaction, so a shift to the right. ✓✓

By LCP, an increase in pressure will shift the equilibrium to the side with fewer gaseous molecules in order to decrease the pressure - in this case, the products, so a shift to the right (3 : 2 ratio). ✓

Therefore, the optimum conditions are:

- a high pressure (which favours both rate and yield) ✓

- a compromise in temperature ✓

The full manufacture of sulphuric acid can be summarised in four main steps.

Step 1 Mining of "pyrite ore", which contains 73% FeS_2.

Step 2 Roasting of the ore to convert the sulphur into sulphur dioxide

$$4\ FeS_2\ (s) + 11\ O_2(g) \rightarrow 2\ Fe_2O_3(s) + 8\ SO_2(g)$$

Step 3 The Contact Process, which is only 68% efficient.

$$\mathbf{8}\ SO_2(g) + \mathbf{4}\ O_2(g) \rightleftarrows \mathbf{8}\ SO_3(g) \qquad (68\%\ \text{efficient})$$

Step 4 Reaction of with water to form sulphuric acid

$$\mathbf{8}\ SO_3(g) + \mathbf{8}\ H_2O(l) \rightarrow \mathbf{8}\ H_2SO_4(aq)$$

(c) Calculate the mass of sulphuric acid that can be produced from 1 tonne (1000 kg) of "pyrite ore".

(7 marks)

Assuming 100% efficiency:

$m(FeS_2) = 1\ 000\ 000 \times 73/100 = 7.30 \times 10^5$ g ✓

$n(FeS_2) = 7.30 \times 10^5 / 119.97 = 6.085 \times 10^3$ ✓

$n(H_2SO_4) = 2 \times n(FeS_2) = 1.217 \times 10^4$ ✓✓✓

$m(H_2SO_4) = 1.217 \times 10^4 \times 98.076 = 1.194 \times 10^6$ g ✓

Taking into account efficiency:

$m(H_2SO_4) = 1.194 \times 10^6 \times 68/100 = 8.116 \times 10^5$ g = <u>812 kg</u> ✓

(e) The commercial concentrated sulphuric acid produced in the above process has a concentration of 18 mol L^{-1}. Using the above quantities, what volume of this acid can be formed?

(2 marks)

$n(H_2SO_4) = m/M = 8.116 \times 10^5 / 98.076 = 8\ 275$ mol ✓

$V(H_2SO_4) = n/c = 8\ 275 / 18 =$ <u>460 L</u> ✓

Question 38 (14 marks)

This question concerns the three elements sodium, potassium and magnesium

(a) Write equations to represent the first and seventh ionisation energies of sodium. (2 marks)

1st I.E. **$Na(g) \rightarrow Na^+(g) + e^-$** ✓

7th I.E. **$Na^{6+}(g) \rightarrow Na^{7+}(g) + e^-$** ✓

(b) Sketch a graph to show the trend in **all** the ionisation energies of sodium. (3 marks)

✓ **(big increase from 9 to 10)**

Energy

✓ **(steady increase from 2 to 9)**

✓ **(big increase from 1 to 2)**

1 2 3 4 5 6 7 8 9 10 11 Ionisation energies

(c) Explain the shape of the above graph. (3 marks)

Electron configuration of sodium is 2.8.1

The first electron is fairly easy to remove. There is a large jump in IE for the 2nd electron as it is being removed from an energy level closer to the nucleus, hence it experiences a greater force of attraction. ✓

IE 2 to 9: there is a moderate increase as the electrons are all in the same shell but it gets progressively harder to remove an electron from an increasingly positive ion. ✓

IE 9 to 10: again there is large jump in IE for the 10th electron as it is a new electron shell closer to the nucleus, with less shielding. ✓

IE 10 to 11: as for IE 2 to 9

(d) Which will have the higher 1st ionisation energy, sodium or potassium? Explain. (3 marks)

Sodium has the higher first IE ✓

K 2.8.8.1 Na is 2.8.1

Although potassium has more protons than sodium, ✓
its valence electron is located further from the nucleus ✓
(or increased nuclear charge is negated by the increase in shielding from inner shell electrons)

Hence, in K, there is a weaker force of attraction between the nucleus and the electron (less shielding) and hence lower IE.

(e) Arrange the three elements (Na, K, Mg) in order of increasing electronegativity and explain your choice. (3 marks)

Order: lowest **K < Na < Mg** ✓ highest

Explanation:

Across the period:

Electronegativity increases due to the increase in nuclear charge with electrons in same shell (similar shielding), hence Na < Mg ✓

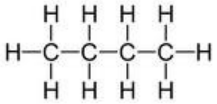
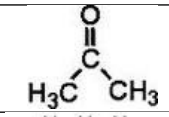
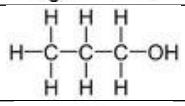
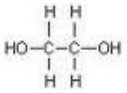
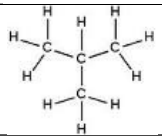
Down a group:

Although nuclear charge increases, valence electrons are further from the nucleus (there is a greater degree of shielding from inner shell electrons), hence K < Na ✓

Question 39 **(14 marks)**

(a) Consider the organic compounds in the table below. Using your knowledge of structure and bonding, arrange these compounds in order of decreasing boiling point in the table below.

(3 marks)

Substance	Name	molar mass	Boiling point (1= highest, 5= lowest)
	butane	58	**4**
	propanone	58	**3**
	propan-1-ol	60	**2**
	ethane-1,2,diol	62	**1**
	methylpropane	58	**5**

5 correct = 3 marks, 3 correct = 2 marks 1 or 2 correct = 1 mark

(b) In the space below give your reasoning for your choices in (a). (6 marks)

Boiling point depends on the strength of the intermolecular forces, the stronger the forces of attraction between molecules the higher the boiling point. ✓

Methylpropane and butane are both non-polar molecules with dispersion forces and hence have the lowest boiling points. Linear molecules tend to have a higher boiling point than their branched isomers due to more interactions along the length of the chain, hence butane > methylpropane. ✓✓

Propanone is a polar molecule with dipole-dipole interactions and will have a higher b.pt than the hydrocarbons but lower than the alcohols. ✓

Both propan-1-ol and ethan-1,2-diol have similar dispersion forces, both have hydrogen bonding between molecules but ethan-1,2-diol has two OH groups hence will have greater degree of hydrogen bonding between molecules. ✓✓

(c) The simplest amino acid, glycine, has the formula H_2NCH_2COOH.

(i) In the above list of decreasing boiling points, whereabouts would you expect glycine to be positioned? Explain your reasoning.

(2 marks)

Glycine has hydrogen bonding between molecules (NH_2 group and OH group) and hence you would expect it to be close to ethan-1-2 diol. ✓

Its molar mass is 75 which is greater than ethan1,2-diol and hence its dispersion forces are stronger so you would predict it to have the highest boiling point. ✓

Alternatively:
α-amino acids exist as zwitterions, i.e. molecules containing localised positive and negative charges, leading to a degree of ionic attraction between molecules, ∴ the highest

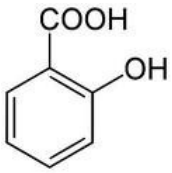
(ii) Predict the shapes of the arrangement of the bonds around each of the atoms highlighted in bold in the table below:

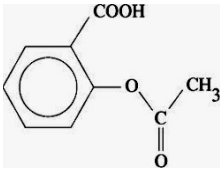
(3 marks)

	Shape
H_2**N**CH_2COOH	**pyramidal** ✓
H_2N**C**H_2COOH	**tetrahedral** ✓
H_2NCH_2**C**OOH	**trigonal planar** ✓

Question 40 **(13 marks)**

Aspirin can be manufactured using the following reaction:



+ CH_3COOH → 

+ **H_2O** ✓

salicylic acid ethanoic acid aspirin

(a) Complete the equation by filling in the box above. (1 mark)

(b) Name the two main functional groups in aspirin. (2 marks)

carboxylic acid ✓ and **ester** ✓

In a particular production of aspirin, 100g of salicylic acid is reacted with 50g of ethanoic acid.

(c) Identify the limiting reactant. (4 marks)

n(salicyclic acid, $C_7H_6O_3$) = 100 / 138.118 = 0.7240 mol ✓

n(CH_3COOH) = 50 / 60.032 = 0.8329 mol ✓

$n(C_7H_6O_3)_{required}$ = n(CH_3COOH) = 0.8329 > 0.7240 ✓

∴ salicyclic acid is the LR. ✓

(d) Calculate the mass of aspirin that can be produced, assuming the process is 100% efficient. (2 marks)

n(aspirin) = 0.7240
m(aspirin, $C_9H_8O_4$) = 0.7240 x 180.064 ✓
= <u>130 g</u> ✓

(e) Calculate the mass of excess reactant remaining after the reaction. (2 marks)

n(CH_3COOH) unreacted = 0.8329 – 0.7240
= 0.1089 ✓

m(CH_3COOH) unreacted = 0.1089 x 60.032
= <u>6.54 g</u> ✓

(f) Aspirin tablets normally contain 300 mg of aspirin. Assuming that it is totally soluble, what would be the concentration of aspirin in the blood, in mg L^{-1}, of an average human with 4.70 L of blood if he took two aspirin tablets. (2 marks)

Concentration = (2 x 300) / 4.70 = <u>127.7 mg L^{-1}</u> ✓✓

Question 41 **(17 marks)**

An unknown alpha amino acid, X, was subjected to analysis in order to determine its formula.

1st experiment 2.07g of X was completely burned in excess oxygen and 3.07g of carbon dioxide and 1.47g of water were formed.

2nd experiment 1.68g of X was reacted so as to convert all the nitrogen into nitrogen (N_2) gas. It was found that the gas formed occupied 211mL, measured at S.T.P.

3rd experiment 1.39g of X was vapourised at 200°C and 105kPa and was found to occupy a volume of 584mL

(a) Calculate the empirical formula of X. (12 marks)

$n(CO_2)$ = 3.07 / 44.01 = 0.06976

n(C) = $n(CO_2)$ = 0.06976

m(C) = 0.06976 x 12.01 = 0.838 g

% C = 0.838/ 2.07x 100 = 40.47% ✓✓

$n(H_2O)$ = 1.47 / 18.016 = 0.08516

n(H) = 2 x $n(H_2O)$ = 0.1630

m(H) = 0.1630 x 1.008 = 0.164 g

% H = 100 x 0.164 / 2.07 = 7.95% ✓✓

(N_2) = V / 22.41 = 0.211 / 22.41 = 0.00941 ✓

n(N) = 2 x $n(N_2)$ = 0.0188

m(N) = 0.0188 x 14.01 = 0.264 ✓

%N = 0.264/1.68 x 100 = 15.7% ✓

% O = 100 - %(C+H+O) = 100 – (40.47 + 7.95 – 15.7) = 35.88 % ✓

C	H	N	O
40.47	7.95	15.7	35.8
12.01	1.008	14.01	16.00
3.37	7.887	1.121	2.242
		1.121	
3	7	1	2

Empirical Formula is $C_3H_7NO_2$ ✓

(b) Calculate the molecular formula of X. (3 marks)

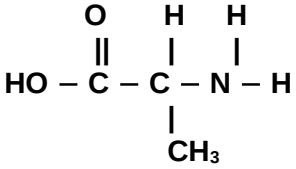
n = PV / RT = (105 x 0.584) / (8.315 x 473.1) = 0.01559 mol

M = m/n = 1.39 / 0.01559 = 89.1 g mol^{-1} ✓

EFM = 89.1

∴ MF = EF = $C_3H_7NO_2$ ✓

(c) Using your knowledge of the structure of alpha amino acids, draw the only possible structural formula of X. (2 marks)



✓✓

END OF EXAMINATION