Year 12 Chemistry
Mid-Year Examination, 2013

Marking Key

Section 1 Multiple-choice **25 marks (25% of paper)**

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

End of Section One

Section Two: Short Answer **70 marks (35% of paper)**

This section has **11** questions. Answer **all** questions. Write your answers in the spaces provided.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page
- Continuing an answer. If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes

Question 26 **(6 marks)**

(a) Describe one chemical test that may be used to distinguish between the two colourless liquids methanol and methanal. State the observations with each chemical.

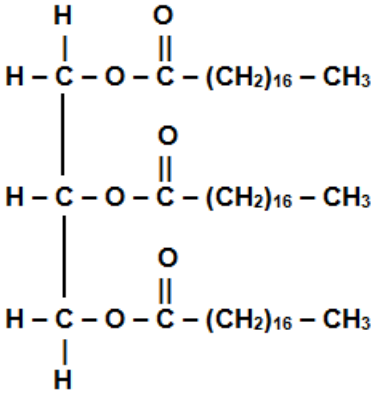
Test: **React with carboxylic acid (e.g. ethanoic acid) with conc. H_2SO_4**
(Note: MP/BP – not acceptable as these are physical test)

Observation with methanol: **Product has a sweet fruity smell**

Observation with methanal: **NVR**

(3 marks)

(b) A soap has the formula $CH_3(CH_2)_{16}COONa$. Draw the structure of the triester (triglyceride) that this soap was prepared from.



(2 marks)

What must be added to this triester to produce soap? **NaOH(aq) / KOH(aq)**

(1 mark)

Question 27 **(4 marks)**

Iron(III) chloride dissolves in water to form a pale brown solution. Over time, a brown precipitate of $Fe(OH)_3$ is formed, establishing the following equilibrium:

$$Fe^{3+}(aq) + 3\,H_2O(l) \rightleftarrows Fe(OH)_3(s) + 3\,H^+(aq)$$

(a) Give one observation when some $Fe(OH)_3(s)$ is added to above equilibrium.

More solid is present (NVR also accepted)

(1 mark)

(b) What chemical could be added to a solution of iron(III) chloride to prevent the precipitation of iron(III) hydroxide? Give a reason why this would reduce precipitation.

Chemical recommended: **addition of an acid, e.g. HCℓ(aq)**

(1 mark)

Reason:

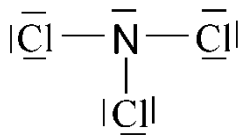
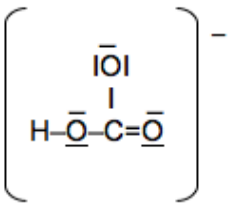
Adding acid ↑[H^+] in solution

By LCP, equilibrium will shift left to partially ↓[H^+]
and hence limits the extent of the forward reaction
(and the precipitation of iron(III) chloride)

(2 marks)

Question 28 **(4 marks)**

For each species listed in the table below, draw the structural formula, representing all valence shell electron pairs as : or as –

nitrogen trichloride, $NCℓ_3$	hydrogencarbonate ion, HCO_3^-
	

Question 29 **(7 marks)**

(a) The first ionisation energies of five **consecutive** elements of the Periodic Table are shown below.

Element	First Ionisation Energy (kJ mol^{-1})
V	1310
W	1680
X	2080
Y	495
Z	733

Which element in the above table would be a halogen? **W** (1 mark)

(b) Place the following in order of increasing 1st ionisation energy Mg, Na, Cs, Cℓ, P
Cs < Na < Mg < P < Cℓ

(1 mark)

Give an explanation for your answer.

Across a period, there is an increase in nuclear charge , while shielding remains relatively constant since all elements have electrons is same shell.

Therefore, moving across the period there is a stronger attraction between valence electrons and nucleus, so IE increases (Na < Mg < P < Cℓ) **½**

Down a group, there is an increase in nuclear charge , while shielding increases due to a greater number of inner shells .

Therefore, moving down the group there is a weaker force of attraction between valence electrons and nucleus, so IE decreases (Cs < Na) **½**

(5 marks)

Question 30 **(6 marks)**

(a) Write ionic chemical equations for the following:

(i) The reaction between a green solid and a colourless solution that produces a colourless gas and a blue solution.

$$\mathbf{CuCO_3(s) + 2\ H^+(aq) \rightarrow Cu^{2+}(aq) + H_2O(l) + CO_2(g)}$$ □□

(2 marks)

(ii) Excess cobalt(II) nitrate solution is added to sodium phosphate solution.

$$\mathbf{3\ Co^{2+}(aq) + 2\ PO_4^{3-}(aq) \rightarrow Co_3(PO_4)_2(s)}$$ □□

(2 marks)

(b) Give complete observations for the reaction that occurred in (ii) above.

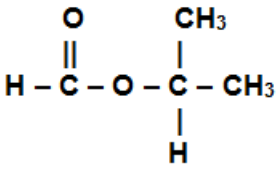
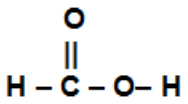
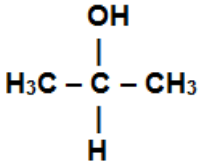
Pink solution is added to a colourless solution, pink precipitate forms <u>and</u> the solution remains pink. □□

(2 marks)

Question 31 **(6 marks)**

A sweet smelling liquid, **A**, has a molecular formula $C_4H_8O_2$. **A** was prepared from reacting liquids **B** and **C** in the presence of concentrated H_2SO_4.

Liquid **C** when oxidised by MnO_4^-/H^+ produced a ketone.

Name of Liquid **A** **2-propylmethanoate**	Structure of Liquid **A** 
Name of Liquid **B** **methanoic acid**	Structure of Liquid **B** 
Name of Liquid **C** **propan-2-ol** **(2-propanol)**	Structure of Liquid **C** 

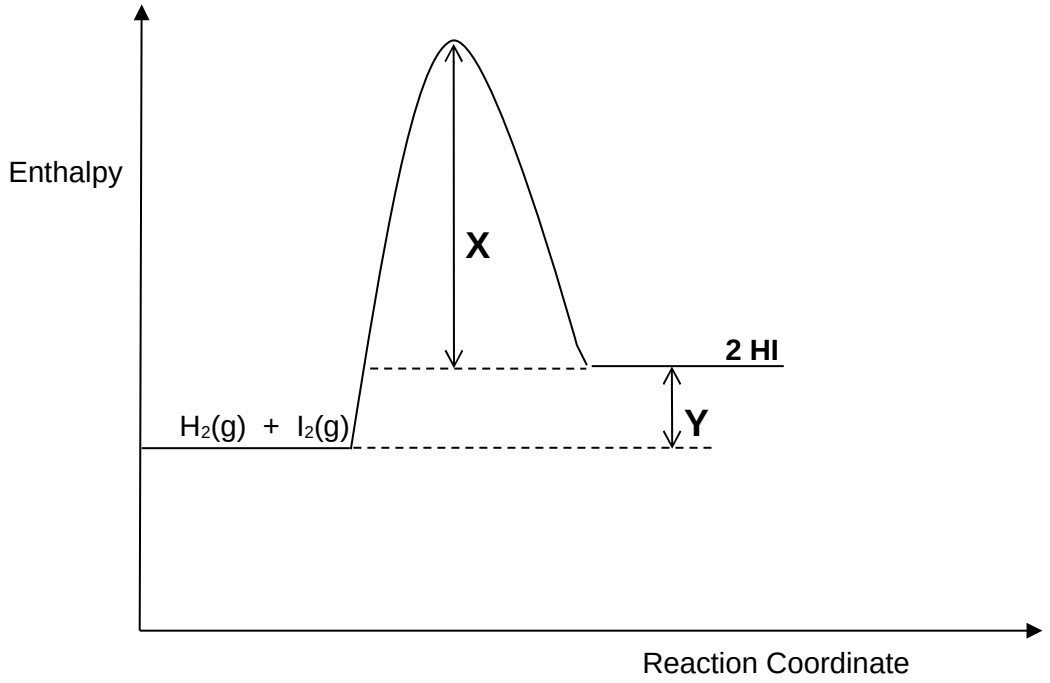
□ **each**

Question 32 **(6 marks)**

Shown below is the energy profile diagram for the reversible reaction:

$$H_2(g) + I_2(g) \rightleftarrows 2HI(g)$$

Answer the following questions in terms of X and Y. You may have to use > (greater than) and < (less than) signs in your responses.



(a) What is the enthalpy change [ΔH] for the forward reaction? **Y**

(b) What is the enthalpy change [ΔH] for the reverse reaction? **–Y**

(c) What is the activation energy for the forward reaction? **X + Y**

(d) What is the activation energy for the reverse reaction? **X**

(e) What is the ΔH for the forward reaction if a catalyst is used? **Y**

(f) What would be the activation energy of the pathway provided by a catalyst for the forward reaction? **< (X + Y)**

 each

Question 33 **(7 marks)**

Aluminium (Aℓ), magnesium (Mg), sulfur (S_8) and phosphorus (P_4) are all elemental solids in period 3 of the Periodic Table.

List the melting points of these solids in *increasing* order **$P_4 < S_8 <$ Mg < Aℓ**

(1 mark)

Justify your answer.

Melting points depends on the strength of the bonds which need to be overcome during the phase change. The stronger the bonds, the higher the melting point.

Mg < Aℓ:
Metallic bonds present which are strong bonds between cations and delocalised electrons hence their m.pt is higher than the molecules.

The melting point of metals depends on the size of the cationic charge and the radius. ✓
As they are both in the same period the radius is similar (Aℓ slightly smaller) but Aℓ is 3+ whereas Mg is 2+, hence Aℓ has the higher m.pt. ✓

$P_4 < S_8$:

Both are non-polar covalent molecular substances with weak dispersion forces between molecules, it is the strength of the dispersion forces which determines m.pt in this case. ✓

The dispersion forces increase in strength with an increasing number of protons & electrons, hence $P_4 < S_8$.

(6 marks)

Question 34 **(8 marks)**

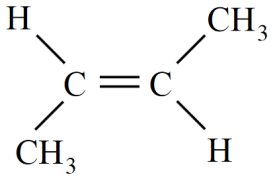
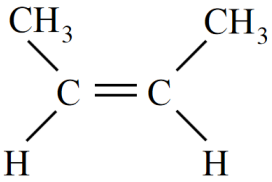
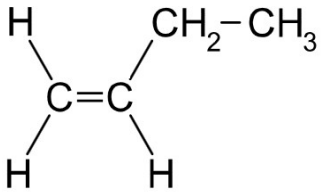
Three hydrocarbons **X**, **Y** and **Z** undergo addition reactions with HBr(g).

Hydrocarbons **X** and **Y** gives a **single** product 2-bromobutane.

On addition reaction with HBr compound **Z** can produce two products, **T** and **L**.

L is also 2-bromobutane.

Complete this table:

Compound	Structure	IUPAC Name
X & Y		***trans*-but-2-ene (*trans*-2-butene)**
		***cis*-but-2 ene (*cis*-2-butene)**
Z		**but-1-ene (1-butene)**
T	**$CH_3CH_2CH_2CH_2Br$**	**1-bromobutane**

 each

Question 35 **(11 marks)**

Chlorine reacts with carbon monoxide as follows:

$$C\ell_2(g) + CO(g) \rightleftarrows COC\ell_2(g) \qquad \Delta H < 0$$

(a) Consider the imposed changes described below and identify the change which has occurred to the total pressure in the container, the concentration of CO and the mass of CO, once equilibrium has been re-established. Complete this table by writing increase, decrease or no change.

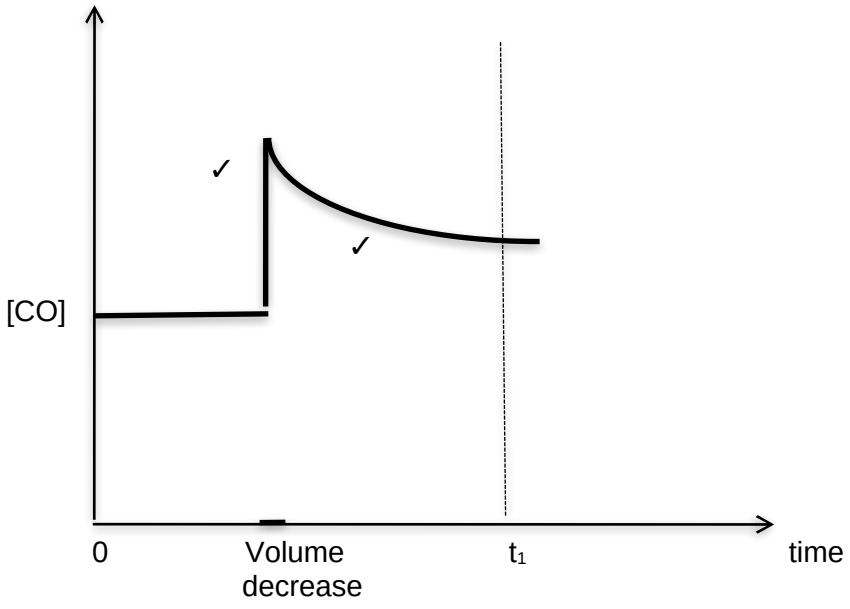
(9 marks)

Imposed Change	Total pressure in the container	Concentration of CO	Mass of CO
(i) The volume of the container is decreased	**increase**	**increase**	**decrease**
(ii) The temperature of the system is increased	**increase**	**increase**	**increase**
(iii) Ne(g) is added at constant volume	**increase**	**no change**	**no change**

 each

(b) Complete the sketch below for imposed change (i) until equilibrium is re-established at t_1.

(2 marks)



Question 36 **(5 marks)**

A and **B** are both amino acids.

A : H_2NCH_2COOH and **B**: $H_2NCH_2CH_2COOH$

(a) Which of the two amino acids above is **not** an α-amino acid? **B**

(1 mark)

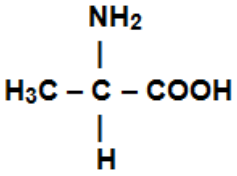
Justify your choice

An α-amino acid must have the NH_2 and the COOH groups attached to the same carbon. B has them on two different carbons.

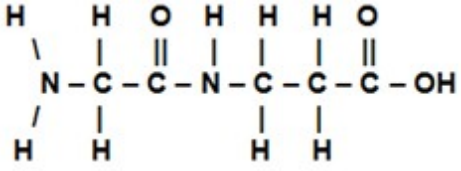
(1 mark)

(b) The non α-amino acid identified in (a) can be redrawn as an isomer that is an α-amino acid. Draw this isomer.

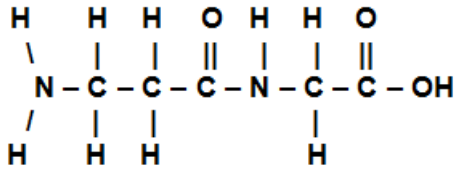
(1 mark)



(c) Dipeptides are the major organic product formed when two amino acids react. Draw one dipeptide formed in the reaction between **A** and **B**.



or



(2 marks)

(1 mark if a polymer structure given with correct peptide bond)

End of Section Two

Section Three: Extended answer 80 marks (40% of paper)

This section contains **five** questions. You must answer **all** questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to three (3) significant figures.

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Suggested working time: 70 minutes

Question 37 (19 marks)

2.42 g of substance **X,** containing only the elements carbon, hydrogen and oxygen was divided into two equal samples. The first sample, on complete combustion in a dry stream of oxygen produced 3.03 g of carbon dioxide. The second sample produced 1.24 g of water under the same experimental conditions.

(a) Determine the empirical formula of substance **X**.

$n(CO_2) = m/M = 3.03/44.01 = 0.06885$ mol
$n(C) = n(CO_2) = 0.06885$ mol
$m(C) = n.M = 0.06885 \times 12.01 = 0.8269$ g

$n(H_2O) = m.M = 1.24/18.016 = 0.06883$ mol
$n(H) = 2.n(H_2O) = 0.1377$ mol
$m(H) = n.M = 0.1377 \times 1.008 = 0.1388$ g

$m(O) = 1.21 - m(C) - m(H) = 0.2443$ g
$n(O) = m/M = 0/2443/16 = 0.01527$ mol

	C	H	O	
n	**0.06885**	**0.1377**	**0.01527**	
		0.01527		
	4.51	**9.03**	**1**	
X 2	**9**	**18**	**2**	

EF = $C_9H_{18}O_2$

(6 marks)

Question 37 continued

(b) When vapourised, a 0.650 g sample of **X** was found to occupy 48.1 mL at a pressure of 213 kPa and temperature of 27°C. Determine the molecular formula of **X**.

n(X) = PV/RT = (213 x 0.0481)/(8.315 x 300.15) = 0.004106 mol ✓

M(X) = m/n = 0.650/0.04106 = 158 g mol^{-1} ✓

M($C_9H_{18}O_2$) = 158.234 ✓

MF = $C_9H_{18}O_2$ ✓

(4 marks)

(c) Substance **X** is an ester. Write a balanced equation showing how the ester ethylpropanoate could be made.

$$CH_3CH_2OH + CH_3CH_2COOH \xrightarrow{H^+} CH_3CH_2COOCH_2CH_3 + H_2O$$ ✓✓

(Note: must have water for 2 marks)

(2 marks)

(d) When the ester 1-octylmethanoate is treated with concentrated acid, two substances **Y** and **Z** are made.

Complete the table below giving the structural formula of **Y** and **Z**.

(2 marks)

Structure	Solubility in water
HCOOH **(methanoic acid)**	Miscible
$CH_3(CH_2)_6CH_2OH$ **(octan-1-ol / 1-octanol)**	Immiscible

✓✓**each**

Question 37 continued

(e) Give a full account of the bonding present in pure samples of ethanoic acid and hexan-1-ol and explain the difference in their solubility in water.

(5 marks)

Ethanoic acid and hexan-1-ol have hydrogen bonding and dispersion forces between molecules

Dispersion forces more predominant IMF between hexan-1-ol molecules due to longer hydrocarbon chain

Water also contains hydrogen bonds between water molecules.

Ethanoic acid, will be soluble in water since it will form hydrogen bonds with water, and its hydrocarbon chain is relatively small. ✓

Hexan-1-ol can form hydrogen bonds with water molecules via its –OH group, however only weak dispersion forces form between water and the hydrocarbon chain. These are much weaker than both hydrogen bonds between eater molecules and dispersion forces between hexan-1-ol molecules - and so will have limited solubility in water. ✓✓

Question 38 **(14 marks)**

0.452 g of a mixture of barium chloride and barium hydroxide was dissolved in water and made up to a volume of 50.0 mL. This solution required 14.3 mL of 0.115 mol L^{-1} hydrochloric acid for neutralisation.

(a) Determine the moles of barium hydroxide in the 0.452 g mixture. (3 marks)

$H^+(aq) + OH^-(aq) \rightarrow H_2O$

$n(HC\ell) = c.V = 0.115 \times 0.0143 = 0.001645$ mol ✓

$n(OH^-)_{Ba(OH)2} = n(HC\ell) = 0.001645$ mol ✓

$n(Ba(OH)_2) = ½\ n(OH^-) =$ <u>0.000822 mol</u> ✓

(b) Determine the mass of barium chloride in the 0.452 g mixture. (2 marks)

$m(Ba(OH)_2) = n.M = 0.000822 \times 171.316 = 0.1409$ g ✓

$m(BaC\ell_2) = 0.452 - 0.1409 =$ <u>0.311 g</u> ✓

(c) What is the concentration of barium ions in solution after neutralisation? (5 marks)

$n(Ba^{2+})_{Ba(OH)2} = 0.000822$ mol ☐

$n(Ba^{2+})_{BaC\ell2} =$ m/M = 0.311 / 208.2 = 0.001494 mol ☐

$n(Ba^{2+})_{total} = 0.002316$ mol ☐

$V_{total} = 0.0643$ L ☐

$c(Ba^{2+}) = n/V = 0.002316 / 0.0643 =$ <u>0.0360 mol L^{-1}</u> ☐

(d) What volume of 0.0500 mol L^{-1} of silver nitrate solution would be required to precipitate the chloride ions from the solution after the addition of $HC\ell$(aq)? (4 marks)

$n(C\ell^-)_{BaC\ell2} = 2.n(BaC\ell_2) = 2 \times 0.001494 = 0.002988$ mol ✓

$n(C\ell^-)_{HC\ell} = n(HC\ell) = 0.001645$ mol ☐

$n(C\ell^-)_{total} = 0.002988 + 0.001645 = 0.004633$ ✓

$n(AgNO_3) = n(Ag^+) = n(C\ell^-) = 0.004633$ ✓

$V(AgNO_3) = n/c = 0.004633 / 0.0500 =$ <u>0.0927 L</u> (or <u>92.7 mL</u>) ✓

Note: –1 mark overall for incorrect use of significant figures for this question

Question 39 **(11 marks)**

Sodium azide, NaN_3, is used in car airbags and escape chutes in aircraft and decomposes at high temperature to produce nitrogen gas. Sodium metal produced in the reaction subsequently reacts with potassium nitrate and silicon dioxide to produce harmless substances, including potassium silicate glass and sodium silicate glass. The reactions involved and their percentage efficiencies are shown below.

Reaction 1: $2\ NaN_3 \rightarrow 2\ Na + 3\ N_2(g)$ 97%

Reaction 2: $10\ Na + 2\ KNO_3 \rightarrow K_2O + 5\ Na_2O + N_2(g)$ 99%

Reaction 3: $K_2O + Na_2O + 2\ SiO_2 \rightarrow K_2O_3Si + Na_2O_3Si$ 92%
silicate glass

If 80.0 g of sodium azide are used in a typical airbag calculate the following:

(a) The number of moles of sodium produced in reaction 1. (2 marks)

$n(NaN_3) = m/M = 80 / 65.02 = 1.230$ mol ✓

$n(Na) = 1.230 \times 0.97 =$ <u>1.19 moles</u> ✓

(b) The number of moles of potassium oxide produced in reaction 2. (2 marks)

$n(K_2O) = 1/10.n(Na) = 1/10 \times 1.19 = 0.119$ mol ✓

Taking into account efficiency:

$n(K_2O) = 0.119 \times 99/100 =$ <u>0.118 mol</u> ✓

(c) The mass of the sodium silicate glass, Na_2O_3Si, produced in reaction 3. (2 marks)

$n(Na_2O_3Si) = n(K_2O) = 0.118$ mol

Taking into account efficiency:

$n(Na_2O_3Si) = 0.118 \times 92/100 = 0.1087$ mol ✓

$m(Na_2O_3Si) = n.M = 0.1087 \times 122.07 =$ <u>13.3 g</u> ✓

(d) The volume of nitrogen gas produced at 101.3 kPa and 25°C. (5 marks)

$n(N_2)_{Reaction\ 1} = 3/2\ n(Na) = 3/2 \times 1.19 = 1.785$ mol ✓

$n(N_2)_{Reaction\ 2} = n(K_2O) = 0.118$ mol ✓

$n(N_2)_{total} = 1.908$ ✓

$V = nRT/P = (1.908 \times 8.314 \times 298.15)/101.3 =$ <u>46.7 L</u> ✓

Note: 3 marks max if N_2 from only from reaction 1 (43.7 L) or reaction 2 (2.89 L)

Question 40 **(17 marks)**

Methanal (CH_2O) is an important industrial chemical. It is made by the oxidation of methanol:

$$2\ CH_3OH(g)\ +\ O_2(g)\ \rightleftarrows\ 2\ CH_2O(g)\ +\ 2\ H_2O(g) \qquad \Delta H = -570\ kJ\ mol^{-1}$$

(a) If the temperature of a sample of this system at equilibrium is raised what effect will this have on the value of the equilibrium constant K? Give the equilibrium expression and explain the effect of temperature change.

$$\mathbf{K = \frac{[H_2O]^2.[CH_2O]^2}{[CH_3OH]^2.[O_2]}}$$

(1 mark)

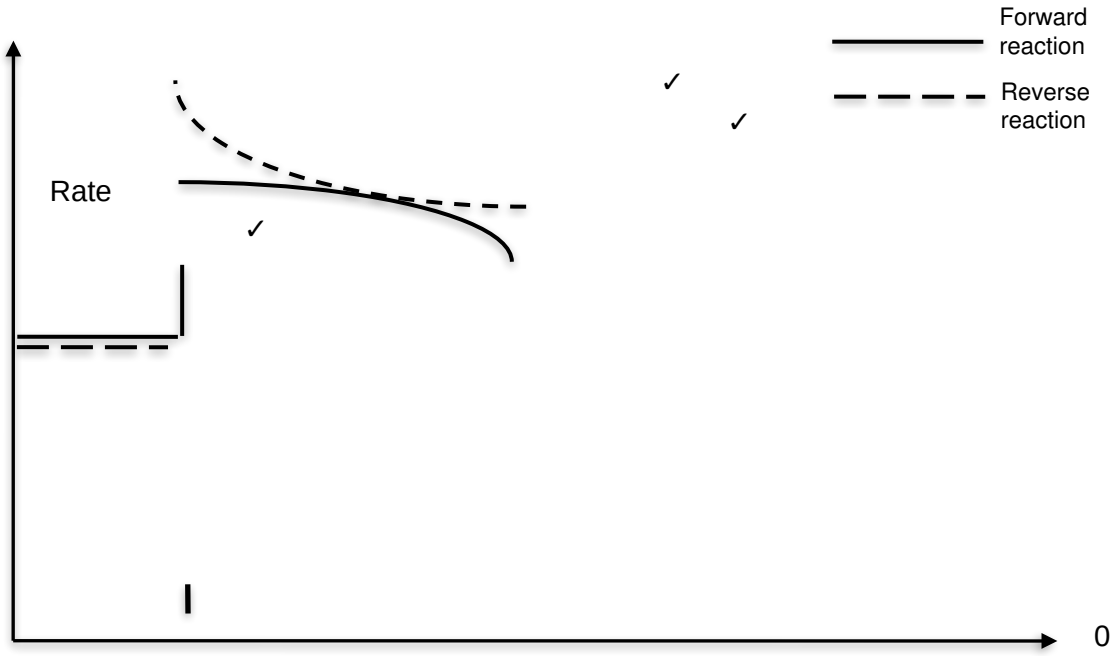
Explanation:

By LCP, as temperature is increased, the endothermic (reverse) reaction

is favoured, hence less products are formed and the value of K would <u>decrease</u>. ✓

(2 marks)

(b) Complete the graph to show the changes in reaction rate associated with an increase of temperature in the sample until equilibrium is re-established.



(3 marks)

Note: Alternative interpretations accepted

Question 40 continued

(c) Predict what temperature and pressure conditions (high, low or moderate) would be most favourable for producing methanal industrially and explain your prediction using the Collision Theory and Le Chatelier's Principle.

(6 marks)

Temperature

A high temperature will increase the rate of the reaction by:
- increasing collision frequency; and
- increasing the proportion of particles with energy greater than the minimum for reaction. ✓

By LCP, a low temperature will increase yield since the forward reaction is exothermic ✓

Therefore, a compromise is required between rate and yield so a moderate temperature is recommended. ✓

Pressure

A high pressure will increase the rate of the reaction by increasing the collision frequency. ✓

By LCP, a low pressure will increase the yield as product side has a greater number of gaseous molecules.

Therefore, a compromise is required between rate and yield so a moderate pressure is recommended. ✓

Question 40 continued

(d) Propanal, an aldehyde, can be made commercially by reacting carbon monoxide, hydrogen gas and ethene in the presence of a catalyst. In the laboratory, propanal can be made using propan-1-ol in a different reaction to that used commercially.

(i) Give details for the reagent(s) needed for the laboratory preparation of propanal from propan-1-ol and any observations that could be expected.

Reagents: **acidified MnO_4^- or acidified $Cr_2O_7^{2-}$** ✓

(1 mark)

Observation: **acidified MnO_4^- purple to colourless** ✓

or acidified $Cr_2O_7^{2-}$ orange to green

(1 mark)

(ii) If propan-1-ol is added in excess but all other reactants are in the correct stoichiometric ratios, both propanal and propan-1-ol will be present in the final mixture. State a suitable method to separate the two liquids and explain your choice.

Separation method:

Distillation (fractional) ✓

(1 mark)

Explanation:

The liquids will have different boiling points.

Propan-1-ol and propanal have similar mass/shape, however propan-1-ol has hydrogen bonding between molecules and propanal has dipole-dipole forces between the molecules. ✓

The dipole-dipole forces are weaker than the hydrogen bonds and hence propanal will be distilled off first.

(2 marks)

Question 41 **(19 marks)**

The physical properties of substances can be explained using knowledge of bonding and atomic structure.

(a) Examine the table of physical properties for a number of elements and their associated oxides.

Element	Melting Point (°C)	First Ionisation Energy (MJ mol^{-1})	Electrical conductivity (MS m^{-1})	Oxide and melting point (°C)
Sodium	98	0.49	20	Na_2O 801
Potassium	63	0.43	14	Not given
Germanium	937	0.77	1×10^{-6}	GeO_2 1150
Chlorine	–101	1.25	0	$C\ell O_2$ –59

(i) State and explain the type of bonding present in germanium.

(3 marks)

Germanium will be a covalent network substance ✓

It has a very low electrical conductivity and hence could not be a metal ✓

It has a high melting point and so it could not be a covalent molecule hence the properties are indicative of a network structure

Note: Germanium cannot be ionic as it is NOT a compound. It is an element and so can only be metallic, covalent molecular, covalent network or atomic

(ii) Explain why sodium has a higher first ionisation energy than potassium.

(2 marks)

Potassium has more protons (greater nuclear charge) than sodium.

Potassium has greater shielding than sodium due to a greater number of inner electron shells *(or explain in terms of radius)*

Hence it will be easier to remove the most loosely bound electron in potassium

(iii) Explain why both sodium and potassium have high electrical conductivity while germanium and chlorine have conductivities that are effectively zero.

(2 marks)

Electrical conductivity requires mobile charge particles.

Sodium and potassium are both metals and have delocalised electrons in a lattice of positive ions, hence metals conduct since the electrons are mobile. ✓

Covalent molecular and covalent network substance has their valence electrons localised in the covalent bond or as lone pairs of electrons and hence have no mobile charge carriers to allow for conductivity. ✓

(iv) Explain why the oxides given have high melting points with the exception of chlorine.

(3 marks)

Sodium oxide is an ionic compound with strong bonds between the ions and it requires a lot of energy to disrupt the ionic bond and hence it has a high melting point. ✓

GeO_2 is covalent network substance and strong covalent bonds between Ge and O need to be disrupted during melting – hence high melting point. ✓

$C\ell_2O$ is a covalent molecule with weak dipole-dipole forces of attraction between molecules. The covalent bond is not broken during the phase change, only the weak dipole-dipole forces are disrupted and hence it has a low melting point. ✓

(b) The substances below have different boiling points. In the table, rank them in order of decreasing boiling point and explain your choice.

Substance	Molar mass (g mol^{-1})	Boiling points in order (1 = highest, 5 = lowest)
Hexane	86.172	**4**
Butanoic acid	88.104	**1**
2-methylpentane	86.172	**5**
Pentan-1-ol	88.146	**2**
Pentanal	86.130	**3**

(3 marks)

5 correct – 3 marks **3 correct – 2 marks** **2 or 1 correct – 1 mark**

Explanation:

These are all covalent molecules and hence the boiling point will depend on the strength of the intermolecular forces. ✓

Butanoic acid and pentan-1-ol have hydrogen bonding between molecules but these are more extensive in butanoic acid due to C=O providing more sites for formation of hydrogen bonds. ✓

Pentanal has dipole-dipole forces between molecules – these are weaker than hydrogen bonds for molecules of similar size/shape had so will have lower boiling point than the pentan-1-ol. ✓

Hexane and 2-methylpentane are both non-polar molecules with only dispersion forces between their molecules. ✓

Hexane is less compact (more linear) and so there is a greater surface area over which the dispersion forces can act so hexane will have a higher boiling point than 2-methylpentane. ✓

(6 marks)

End of questions