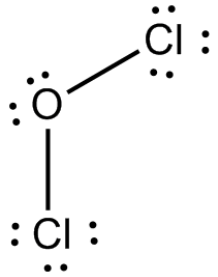
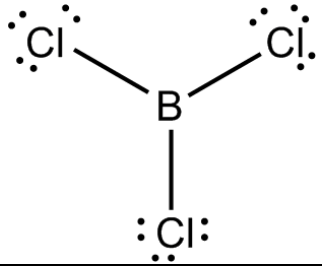
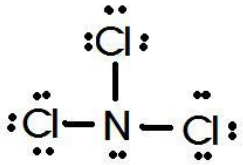
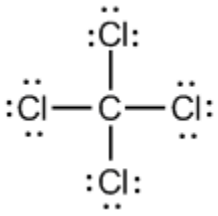
BENCHMARK PRACTICE EXAM ONE

ANSWERS BONDING AND THERMOCHEMISTRY ANSWERS

QUESTION ONE

(a) Complete the following table by

Molecule	Lewis diagram	Name of shape	Polar or non-polar
Cl_2O		Bent	Polar
BCl_3		Triangular planar	Non-polar
NCl_3		Trigonal pyramid	Polar
CCl_4		tetrahedral	Non-polar

3 lines correct = m point

3 shapes correct = a point

3 Lewis diagrams correct = a point

3 polarities correct = a point

Explain why each of the molecules BCl_3 and Cl_2O have the shape you identified in part (a) above.

(i) Cl_2O

There are 4 areas of electron density around the central atom O. These areas occupy positions to minimize repulsion OR repel maximally to form a tetrahedral arrangement. As 2 areas are bonding and 2 are non-bonding, the shape observed is BENT.

(ii) BCl_3

There are 3 areas of electron density around the central atom B. These areas occupy positions to minimize repulsion OR repel maximally to form a triangular planar arrangement. As all 3 areas are bonding, the shape observed is TRIANGULAR PLANAR.

(c) Justify your classification of polar or non-polar in part (a) for each of the molecules BCl_3 and Cl_2O

(i) Cl_2O

There are polar bonds in this molecule as O is more electronegative than Cl. Due to the bent shape, these dipoles are arranged asymmetrically around the central atom, and so the dipoles do not cancel and this molecule is POLAR.

(ii) BCl_3

There are polar bonds in this molecule as Cl is more electronegative than B. Due to the triangular planar shape, these dipoles are arranged symmetrically around the central atom, and so the dipoles do cancel and this molecule is NON-POLAR.

One statement correct for shape (correct # areas bonding and not, repulsion etc) = 1 a point

One statement correct for polarity (eg polar bonds described with reason or cancelling dipoles due to symmetry etc) = 1 a point

One shape explained correctly = 1m point

One polarity explained correctly = 1 m point

Both shapes and polarities correct = 1 e point

N0	N1	N2	A3	A4	M5	M6	E7	E8
Nothing correct	1 a point	2 a points	3a points	4 a points	2 m points	3 m points	1 e point (minor error)	1e point

QUESTION TWO

The table below supplies information about the oxides of some of the third-row elements.

(a) Complete the following table:

Name and formula of solid	**Melting point** °C	**Type of solid** (covalent network, ionic, metallic, or molecular)	**Type of particle(s) in crystal** (atoms, ions or molecules)	**Name of bond broken when the solid melts** (covalent, ionic, metallic or weak intermolecular)
sodium oxide, Na_2O	1275	ionic	ions	Ionic bond
silicon dioxide SiO_2	1710	Covalent network	atoms	Covalent bond
sulfur trioxide SO_3	27	molecular	molecules	WIF
chlorine dioxide ClO_2	–75	molecular	molecules	WIF

3 lines correct = a point

(b) Silica, SiO_2, is a very hard solid with a melting point of 1700 °C.
Sulfur trioxide, SO_3 is a colourless liquid that boils at 45 °C.

Explain the above properties of these two compounds with reference to their structure and bonding

SiO_2 is a covalent network substance. It is a 3-d lattice composed of Si and O atoms bonded to each other by strong covalent bonds. As the covalent bonds are strong, it requires a lot of energy to overcome these bonds and convert solid SiO_2 to a liquid, therefore SiO2 has a high melting point.

SO_3 is a molecular substance. It is a 3D lattice composed of SO_3 molecules bonded to other SO_3 molecules by WIF. As these forces are weak, it requires little energy to overcome them and transform solid SO_3 to a liquid and therefore SO_3 has a low melting point.

Melting point correctly defined = a point

One substance melting point explained correctly = m point

Both substance melting point explained correctly = e point

QUESTION THREE

Iron metal and the compound iron(II) chloride are distinctly different substances. Some physical properties of each are given below.

Iron metal	Iron(II) chloride
High melting point	High melting point
An excellent conductor of electricity in both the solid and molten state.	The solid does not conduct electricity but does in the molten state.

Discuss the similarities and differences in the given properties in these two substances, in terms of the types of particles present and the structure and bonding within the substance.

Fe is a metallic substance. It is a 3-d lattice composed of Fe atoms bonded to each other by strong metallic bonds. The valence e are delocalized /the atoms are in a sea of delocalized valence electrons. As the metallic bonds are strong, it requires a lot of energy to overcome these bonds and convert solid Fe to a liquid, therefore Fe has a high melting point. In the solid structure there are free moving valence electrons (charged), therefore solid and liquid Fe can conduct electricity.

$FeCl_2$ is an ionic substance. It is a 3-d lattice composed of Fe^{2+} and Cl^- ions bonded to each other by strong ionic bonds (electrostatic attraction between positive and negative charges). As the ionic bonds are strong, it requires a lot of energy to overcome these bonds and convert solid $FeCl_2$ to a liquid, therefore $FeCl_2$ has a high melting point. In the solid structure the charged ions are locked into the 3D lattice and are unable to move so solid $FeCl_2$ cannot conduct electricity. However, when molten, the ions are free to move and liquid $FeCl_2$ can conduct electricity.

conductivity correctly defined = a point

partial explanation of one property (not enough for merit) = a point

One substance melting point explained correctly = m point

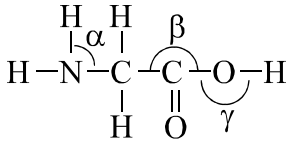
One substance conductivity correctly explained = m point

One substance explained correctly for BOTH conductivity and melting point = e point

N0	N1	N2	A3	A4	M5	M6	E7	E8
Nothing correct	1 a point	2 a points	3a points	4 a points	1 m points	2 m points	1 e point	2e point

QUESTION FOUR

Amino acids are the building blocks of protein. The simplest amino acid is glycine (aminoethanoic acid). The structure of glycine is drawn below, with no attempt to show bond angles correctly.



(a) (i) Complete this diagram by adding the non-bonding electron pairs.

2 e added to the N atom, 2 PAIRS (4e) added to the O atom on the end (to make sure all non-bonding e are used)

e added correctly = 1a point

(ii) Predict the bond angles □□□□□□ and give reasons for your choice. Choose from 90°, 109.5°, 120°, 180°

Bond	Bond angle
□	109.5
□	120
□	109.5

(iii) Explain carefully how you made your choices for the bond angles above.

Bond angles depend only on the number of areas of e density around the central atom, whether bonded or non-bonded. As these areas repel maximally, the angles are 109.5 for 4 areas of e density and 120 for 3 areas of e density.

(b) The structure of a compound can affect it's solubility in water. Using CO_2 and HBr as examples explain why one of these is soluble in water and one is not.

CO2 is non-polar and HBr is polar, water is polar. HBr is soluble in water as the WIF attraction between the HBr and water molecules is sufficient for the HBr to mix with the H_2O and form WIF between the molecules (the forces between HBr molecules and H_2O molecules are less favourable)

Whereas, with non-polar CO_2, the WIF between CO_2 and H_2O is less favourable than either the CO_2-CO_2 forces or the H_2O-H_2O forces, which means the CO_2 is not soluble in water.

INSERT APPROPRIATE DIAGRAM HERE

QUESTION FIVE

(a) State whether each of the following are endothermic or exothermic.

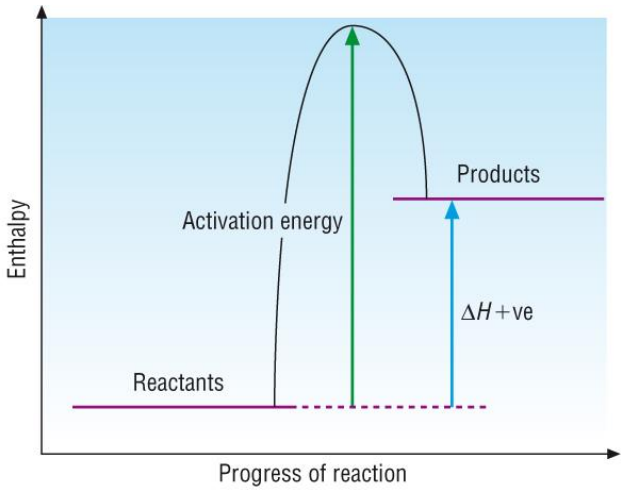
Equation	Endothermic or exothermic
$S(g) + O_2(g) \longrightarrow SO_2(g)$	Probably exo
$H_2O(l) \longrightarrow H_2O(s)$	Exo
Ammonium chloride is dissolved in water and the temperature decreases.	Endo
$Na^+(g) \longrightarrow Na^+(aq)$ $\Delta H = -240$ kJ mol^{-1}	exo

(b) Draw an Enthalpy Diagram for the reaction

$H_2(g) + I_2(g) \longrightarrow 2HI(g)$ $\Delta H = 52$ kJ mol^{-1}

The activation energy for this reaction is 160 kJ mol^{-1}.

On the diagram, you should label the appropriate numbers and the reactants and products formulae.



(c) Calculate the energy change for the above reaction when 3 mol of HI is produced

2mol HI absorbs 52 kJ (from equation), therefore

1 mol HI absorbs 28 kJ and

3 mol HI absorbs 3 x 28 = 84 kJ

(d) What mass of HI would be produced when 364 kJ of energy is absorbed in the above reaction?
M (HI) = 128 $gmol^{-1}$

1 mol HI absorbs 52 kJ therefore

X mol HI absorbs 364 kJ

X = 364/52 = 7 mol. M = nM = 7 x 128 = 896 g of HI

BENCHMARK PRACTICE **ANSWERS** REACTIONS**ANSWERS**

QUESTION ONE

The following reaction was investigated experimentally. The total volume of each experiment was 200 mL. The investigation and results are shown in the table below:

$$S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2$$

Time (minutes)	Mass of I_2 produced (g)			
	0.1 mol $S_2O_8^{2-}$	0.2 mol $S_2O_8^{2-}$	0.4 mol $S_2O_8^{2-}$	0.1 mol $S_2O_8^{2-}$ + Fe^{2+}
2	0.02	0.02	0.03	0.03
4	0.03	0.04	0.06	0.06
6	0.04	0.06	0.06	0.06
8	0.05	0.06	0.06	0.06

(a) What factor affecting reaction rate is being investigated in the first 3 columns?
Concentration

(b) What is the most likely factor affecting reaction rate being investigated in the 4th column?
Catalyst

(c) Write one conclusion that can be made about reaction rate from the table.

The higher the concentration, the faster the rate of reaction OR use of a catalyst increases the rate of reaction

(d) Explain carefully how BOTH factors being investigated affect reaction rate with reference to the collision of particles.

An increased concentration means more particles in the same volume. Therefore there is a higher chance of a successful collision as there are more collisions and so a higher frequency of effective collisions.

A catalyst reduces the Ea by providing a lower energy alternative path. This means that more particles will have sufficient energy to overcome the Ea barrier and therefore ther will be more successful collisions per second

QUESTION TWO

Ammonia is made by the Haber Process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

(a) Write down the form of the equilibrium constant expression for this equilibrium.

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

(b) An industrial plant to produce ammonia is run at 400 °C. Discuss how both rate and equilibrium factors of concentration, pressure and temperature need to be considered when deciding the 'best' temperature for this process.

Equilibrium: To increase the conc of NH_3, you could decrease the temperature, increase the pressure and decrease the conc of NH_3 (remove it as it forms) and/or increase the conc of either of the 2 reactants. By decreasing the temp, the system moves to the side to increase the temp – the exothermic direction. As DH is negative, this is the forward direction, increasing the conc of NH3. Increasing the pressure produces a shift to the side with the fewest moles of gas particles – in this case the right (2 moles compared to the left has 4 moles). This increases the conc of NH3. Increasing the conc of reactants or decreasing the conc of products both produce a shift to the right to make more NH3.

Rate: decreasing the temperature decrease the Ek of the particles, resulting in fewer particles having sufficient energy to overcome Ea barrier and therefore a slower rate of reaction (decreasing the production of NH3 in the same time frame). Increasing the conc of reactants would increase the rate, more particles per mL, means a higher frequency of effective collisions.

Therefore, you would need a low enough temp to move the equilibrium to the right without decreasing the rate too much, a high conc of reactants and a high pressure

(c) The following reaction is exothermic:

$$2N_2O_5(g) \rightleftharpoons 4NO_2(g) + O_2(g)$$

Both N_2O_5 and O_2 are colourless gases and NO_2 is a brown gas.
A mixture of these gases exists at equilibrium and is observed as a brown colour.

(i) Complete the equilibrium constant expression for the reaction.

$Kc = [O_2][NO_2]^4/[N_2O_5]^2$

(ii) The mixture of gases is heated (at constant pressure). Describe the expected observation and explain why this occurs.

Increasing the temperature causes the system to shift in the direction to decrease the temperature – the endothermic direction. AS the reaction is exothermic in the forward direction, this produces a shift to the left. This decreases the $[NO_2]$ which is brown and therefore we see a LIGHTER BROWN

(iii) The concentration of NO_2 is decreased by removing it as it forms. Describe the expected effect of the magnitude of the Kc value.

Kc would not change. The system would oppose the change and re-establish equilibrium. The only thing that changes Kc is temperature

(iv) Calculate the value of Kc if the concentrations at equilibrium are:

N_2O_5 – 0.50 molL^{-1}, NO_2 – 0.80 molL^{-1} O_2 – 0.20 molL^{-1}

$Kc = (0.2)(0.8)^4/(0.5)^2$

$= 0.328$

QUESTION TWO

(a) Complete the equations below to show how each species will react with water.

(i) $NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$

(ii) $C_2H_5COO^- + H_2O \leftrightarrow C_2H_5COOH + OH^-$

(b) Determine the $[H_3O^+]$, $[OH^-]$ and pH of each of the following solutions.

2.47×10^{-2} mol L^{-1} HCl solution

$[H_3O^+]$ /mol L^{-1}	**$[OH^-]$ /mol L^{-1}**	**pH**
2.47×10^{-2}	4.05 x 10^{-13}	1.61

0.0534 mol L^{-1} NaOH solution

$[H_3O^+]$ /mol L^{-1}	**$[OH^-]$ /mol L^{-1}**	**pH**
1.87 x 10^{-13}	0.0534 mol L^{-1}	12.7

(c) Place the following solutions in order of increasing pH, by writing them into the boxes below.

- 0.01 mol L^{-1} CH_3COOH
- 0.01 mol L^{-1} HCl
- 0.1 mol L^{-1} HCl
- 0.1 mol L^{-1} NaOH

0.1 HCl	0.01 HCl	0.01 CH_3COOH	0.1 NaOH

Lowest pH Highest pH

Justify your order above in terms of:

- proton transfer
- relative concentrations of $[H_3O^+]$ and $[OH^-]$, linked to the pH of the solution.

You should include equations in your answer.

$HCl + H_2O \leftrightarrow H_3O_+ + C_{l-}$

$CH_3COOH + H_2O \leftrightarrow CH_3COO^- + H_3O^+$

$NaOH \rightarrow Na+ + OH-$

HCl is a strong acid which fully dissociates into its ions (see equation 1). The 0.1 $molL^{-1}$ HCl is also the most concentrated, so this sample has the highest $[H_3O^+]$ and therefore (as pH = - log $[H_3O^+]$ this sample has the lowest pH. 0.01 molL-1 is also fully dissociated, but as this is less concentrated, the $[H_3O^+]$ is slightly lower and therefore the pH is a little higher.

CH_3COOH is a weak acid which partially dissociates into its ions (see equation 2). 0.01 $molL^{-1}$ is the same concentration as the 2nd HCl, but as this acid is weak, the $[H_3O^+]$ is slightly lower and therefore the pH is a little higher, therefore the 3rd highest pH.

All of these acids produce H_3O^+ so they are all acidic (pH<7)

NaOH is a strong base and fully dissociates into its ions (see equation 3). Since it produces a high concentration of OH- (which is made in the reaction) as it is both strong and concentrated, and therefore the lowest $[H_3O^+]$ (as $[H_3O^+] \times [OH-] = 1 \times 10^{-14}$) this has the highest pH

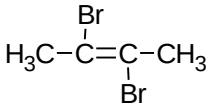
BENCHMARK PRACTICE **ANSWERS**ORGANIC**ANSWERS**

QUESTION ONE

(a) Complete the following table.

Structure	Name
$CH_3CH_2CH(CH_3)CH=CH_2$	(i) 3-methylpent-1-ene
(ii) $CH_3CHClC(CH_3)_2CH_3$	2-chloro-3,3-dimethylbutane
$CH_3CH(Cl)CH_2CH_2COOH$	(iii) 4-chloropentanoic acid
(iv) $C(OH)(CH_3)_3$	methylpropan-2-ol

(b)



The structural formula shown is that of *trans* 1,2-dibromobut-2-ene.

(i) Draw in the box provided, the corresponding *cis* isomer.

Br atoms both up or down

(ii) Discuss the conditions required for *cis-trans* isomerism to occur, using 1,2-dibromobut-2-ene as an example.

Cis-trans isomerism requires 2 conditions:

1. A non-rotational C to C double bond which fixes the atoms in place
2. Each double bonded C atom needs 2 different atoms/groups attached.

1,2-dibromobut-2-ene.has a C to C double bond. Each double bonded C atom is bonded to a Br atom and a CH3 group. Therefore this compound meets both requirements for cis-trans isomerism.

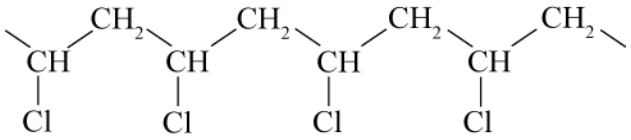
(c) You are given a molecular formula $C_3H_6O_2$. Draw a possible structural formulae for this compound

CH_3CH_2COOH (easiest) but could have an alkene with 2 OH groups.

(d) You are given the molecular formula C_3H_8O. Draw structural formulae for a primary alcohol and a secondary alcohol with this molecular formula.

$CH_3CH_2CH_2OH$ **(primary) and** $CH_3CH_2(OH)CH_3$ **drawn (secondary)**

QUESTION TWO



(a) This structure represents a small section of an addition polymer. In the box below draw the structural formula of the monomer from which it was formed.

$CHCl=CH_2$

(b) You are given the following organic compounds:

1-Hexene $CH_3(CH_2)_3CH=CH_2$ **Hexane $CH_3(CH_2)_4CH_3$**

Ethanol C_2H_5OH **Butanoic Acid $CH_3(CH_2)_2COOH$**

You are also given the following reagents:

hydrogen chloride (HCl), concentrated sulfuric acid (cH_2SO_4), acidified potassium permanganate (MnO_4^-/H^+) and sodium carbonate (Na_2CO_3).

For each of the types of reaction given below choose a possible reactant and reagents from the list and write them in the appropriate boxes. Draw **the structural formulae of the organic products** that would form from the reactions in the appropriate boxes.

(i) Elimination

Organic compound	Reagent	Organic product
Ethanol	cH_2SO_4	Ethene

(ii) **Oxidation to produce a carboxylic acid**

Organic compound	Reagent	Organic product
Ethanol OR 1-hexene	$KMnO_4$ acidified/heat	Ethanoic acid OR hexan-1,2-diol

(iii) Addition

Organic compound	Reagent
Hex-1-ene	HCl

Major organic product	Minor organic product
2-chlorohexane	1-chlorohexane

(iv)Acid/base

Organic compound	Reagent
Butanoic acid	Na_2CO_3

Major organic product	Other products
sodiumbutanoate	CO_2 and H_2O

(c) When **ethane** and **bromine** react a **substitution reaction** takes place. When **ethene** and **bromine** react an **addition reaction** takes place. Use these two examples to discuss the differences between these two types of reaction.

Your discussion should include:

- What is happening in the reaction
- The condition necessary for each reaction to occur
- The rate of the reactions
- The number of products of each reaction
- The structural formulae of the organic products of the reactions

Ethane + Br2 is a substitution reaction, where a Br atom replaces an H atom. This reaction requires UV light and time and is a slow reaction. 2 products are formed as shown:

$CH_3CH_3 + Br_2 \rightarrow CH_3CH_2Br + HBr$

Ethene + Br2 is an addition reaction, where the C to C double bond is broken and 1 new atom is added to each previously double bonded C atom to form a saturated compound. This reaction requires no special conditions, is quick and forms 1 product as shows:

$CH_2CH_2 + Br_2 \rightarrow CH_2BrCH_2Br$

QUESTION THREE

You are asked to identify three colourless liquids: **pent-1-ene, butanoic acid and butan-1-ol**. You are provided with the reagents **bromine water** and **acidified potassium dichromate**.

In your answer you should:

- Devise a scheme that will enable you to identify the three colourless liquids using only the reagents provided.
- Describe what you would do and the observations you would make.
- Write equations for any reactions described showing the organic reactants and products. You do not need to balance the equations.

Add Br_2 to a sample of each solution. In one sample, the orange Br_2 would decolourise rapidly, in the other two it would remain orange. The one that decolourises quickly is the pent-1-ene – remove and label. To the remaining compounds, add acidified dichromate. One sample would turn the orange dichromate green, the other would remain orange. The one that changes to green is the butan-1-ol, the other butanoic acid.

Equation 1: $CH_3(CH_2)_2CHCH_2 + Br_2 \rightarrow CH_3(CH_2)_2CHBrCH_2Br$

Equation 2: $CH_3(CH_2)_3OH + Cr_2O_7^{2-}/H^+ \rightarrow CH_3(CH_2)_2COOH$