Topics in the November 2008 Exam Paper for CHEM1102

Click on the links for resources on each topic.

2008-N-2:

- Periodic Trends in Aqueous Oxide
- Crystal Structures

2008-N-3:

- Solubility Equilibrium
- Hydrolysis of Metal Ions
- Coordination Chemistry

2008-N-4:

- Hydrolysis of Metal Ions
- Coordination Chemistry

2008-N-5:

- Weak Acids and Bases
- Calculations Involving pK_a

2008-N-6:

- Physical States and Phase Diagrams
- Intermolecular Forces and Phase Behaviour

2008-N-7:

- Physical States and Phase Diagrams
- Intermolecular Forces and Phase Behaviour

2008-N-8:

- Kinetics

2008-N-9:

- Kinetics
- Kinetics - Influences

2008-N-10:

- Representations of Molecular Structure
- Carboxylic Acids and Derivatives

2008-N-11:

- Stereochemistry

2008-N-12:

- Alkenes
- Stereochemistry

2008-N-13:

- Alkenes
- Aromatic Compounds

2008-N-14:

- Structural Determination

2008-N-15:

- Synthetic Strategies

	Marks
• Briefly explain how the concept of electronegativity can rationalise the existence of acidic, basic and amphoteric oxides.	3

Oxides of the *least* electronegative elements (the *most* electropositive elements – the metals) are very ionic. They consist of a cation and the oxide, O^{2-}, ion. The oxide ion is *extremely* basic. For example, it will react rapidly with water:

$O^{2-}(aq) + H_2O(l) \rightarrow 2OH^-(aq)$

Dissolution of the oxide of an element of low electronegativity will result in a strongly basic solution.

The oxides of the *most* electronegative elements (the non-metals) are covalent and contain E=O bonds (where E is the electronegative element). They react with water to form acids. For example, sulfur trioxide reacts with water to produce sulfuric acid which rapidly ionizes to give an acidic solution:

$SO_3(aq) + H_2O(l) \rightarrow H_2SO_4(aq) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$

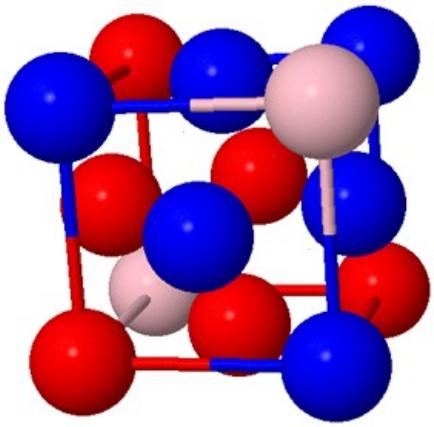
Elements with intermediate electronegativity form oxides which react with both acids and bases. As a result, they are classified as being amphoteric. Aluminium oxide is an example. It will dissolve in acidic and in alkaline solutions according to the reactions:

reacting as a base: $Al_2O_3(s) + 6H^+(aq) + 3H_2O(l) \rightarrow 2[Al(OH_2)_6]^{3+}$
reacting as an acid: $Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \rightarrow 2[Al(OH)_4]^-$

You would *not* have needed to remember these reactions of SO_3 or Al_2O_3 to get full marks on this question. They are given here as examples.

Draw the face-centred cubic unit cell.	2

The face-centred cubic unit cell has one atom on each corner of the cube and one atom on each face. They are no atoms at the centre of the cube.



Marks 4

A solution is prepared that is 0.10 M in potassium bromide and 0.10 M in potassium chromate. A concentrated aqueous solution of silver nitrate is added with stirring. What is the concentration of $Ag^+(aq)$ ions when silver bromide first appears?
K_{sp} of AgBr = 5.0×10^{-13}

When precipitation occurs, the following equilibrium is established and $[Ag^+(aq)]$ and $[Br^-(aq)]$ are controlled by the value of the solubility product:

$$AgBr(s) \rightleftharpoons Ag^+(aq) + Br^-(aq)$$
$$K_{sp} = [Ag^+(aq)][Br^-(aq)] = 5.0 \times 10^{-13}$$

As the solution is 0.10 M in KBr, $[Br^-(aq)] = 0.10$ M:

$$[Ag^+(aq)] \times (0.10) = 5.0 \times 10^{-13} \quad \text{so } [Ag^+(aq)] = 5.0 \times 10^{-12} \text{ M}$$

Answer: **5.0×10^{-12} M**

What is the concentration of $Ag^+(aq)$ ions when silver chromate first appears?
K_{sp} of Ag_2CrO_4 = 2.6×10^{-12}

When precipitation occurs, the following equilibrium is established and $[Ag^+(aq)]$ and $[CrO_4^{2-}(aq)]$ are controlled by the value of the solubility product:

$$Ag_2CrO_4 \rightleftharpoons 2Ag^+(aq) + CrO_4^{2-}(aq)$$
$$K_{sp} = [Ag^+(aq)]^2[CrO_4^{2-}(aq)] = 2.6 \times 10^{-12}$$

As the solution is 0.10 M in K_2CrO_4, $[CrO_4^{2-}(aq)] = 0.10$ M:

$$[Ag^+(aq)]^2 \times (0.10) = 2.6 \times 10^{-12} \quad \text{so } [Ag^+(aq)] = 5.1 \times 10^{-6} \text{ M}$$

Answer: **5.1×10^{-6} M**

What is the concentration of $Br^-(aq)$ ions when silver chromate first appears?

$[Br^-(aq)]$ is control by the K_{sp} for AgBr and so when $[Ag^+(aq)] = 5.1 \times 10^{-6}$ M,

$$K_{sp} = [Ag^+(aq)][Br^-(aq)] = 5.0 \times 10^{-13}$$

$$(5.1 \times 10^{-6}) \times [Br^-(aq)] = 5.0 \times 10^{-13} \quad \text{so } [Br^-(aq)] = 9.8 \times 10^{-8} \text{ M}$$

Answer: **9.8×10^{-8} M**

ANSWER CONTINUES ON THE NEXT PAGE

3

- Calculate the equilibrium constant for the following reaction.

$$AgI(s) + 2CN^-(aq) \rightleftharpoons [Ag(CN)_2]^-(aq) + I^-(aq)$$

Data: K_{stab} of $[Ag(CN)_2]^- = 3 \times 10^{20}$; K_{sp} of $AgI = 8.3 \times 10^{-17}$

The equations for the dissolution of AgI and the stability constant of the complex $[Ag(CN)_2]^-$ are, respectively:

$$\mathbf{AgI(s) \rightleftharpoons Ag^+(aq) + I^-(aq)} \qquad \mathbf{K_{sp} = [Ag^+(aq)][I^-(aq)]}$$

$$\mathbf{Ag^+(aq) + 2CN^-(aq) \rightleftharpoons [Ag(CN)_2]^-(aq)} \qquad \mathbf{K_{stab} = \frac{[[Ag(CN)_2]^-(aq)]}{[Ag^+(aq)][CN^-(aq)]^2}}$$

Addition of these reactions gives the required reaction and so the equilibrium constant for the reaction is the product of the individual equilibrium constants:

$$\mathbf{AgI(s) + 2CN^-(aq) \rightleftharpoons [Ag(CN)_2]^-(aq) + I^-(aq)}$$

$$\mathbf{K = K_{sp} \times K_{stab} = [Ag^+(aq)][I^-(aq)] \times \frac{[[Ag(CN)_2]^-(aq)]}{[Ag^+(aq)][CN^-(aq)]^2}}$$

$$\mathbf{= \frac{[[Ag(CN)_2]^-(aq)][I^-(aq)]}{[CN^-(aq)]^2}}$$

Hence,

$$\mathbf{K = K_{sp} \times K_{stab} = (8.3 \times 10^{-17}) \times (3 \times 10^{20}) = 2 \times 10^4}$$

Answer: $\mathbf{2 \times 10^4}$

- Which of the cations, $[Fe(OH_2)_6]^{3+}$ and $[Fe(OH_2)_6]^{2+}$, has the larger pK_a? Briefly explain why.

Marks 2

Solutions containing both cations are acidic due to the equilibria:

$$[Fe(OH_2)_6]^{2+}(aq) \rightleftharpoons [Fe(OH_2)_5(OH)]^{+}(aq) + H^{+}(aq)$$
$$[Fe(OH_2)_6]^{3+}(aq) \rightleftharpoons [Fe(OH_2)_5(OH)]^{2+}(aq) + H^{+}(aq)$$

The Fe^{2+} and Fe^{3+} cations polarize the Fe-OH_2 bond, pulling electron density from the oxygen. The oxygen, in turn, pulls electron density away towards itself in the O-H bond, causing H^+ to be produced.

Fe^{3+} has a higher charge and is smaller than Fe^{2+}: it is more polarizing and so $[Fe(OH_2)_6]^{3+}$ is more acidic. The equilibrium is further to the right for $[Fe(OH_2)_6]^{3+}$ than it is for $[Fe(OH_2)_6]^{2+}$ so K_a ($[Fe(OH_2)_6]^{3+}$) > K_a ($[Fe(OH_2)_6]^{2+}$).

As pK_a = -$\log_{10}K_a$, a higher K_a means a *lower* pK_a. Thus, $[Fe(OH_2)_6]^{3+}$ is the more acidic of the two cations and has the lower pK_a value.

3

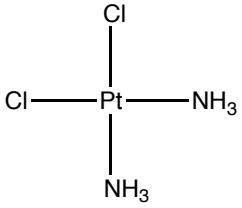
- Consider the compound $[CrCl(OH_2)_4(NCS)]Cl{\cdot}2H_2O$.
The complex ion is $[CrCl(OH_2)_4(NCS)]^+$. This contains Cr^{3+} bonded to Cl^-, $4H_2O$ and one NCS^-. For each ligand, the donor atom is listed *first*.

What is the oxidation state of the transition metal ion?	**+3 or (III)**
What is the coordination number of the transition metal ion?	**6**
How many *d*-electrons in the transition metal ion?	**Cr is in group 6 so Cr(III) is d^3**
List all the ligand donor atoms.	**Cl^-, 4 × O and N**

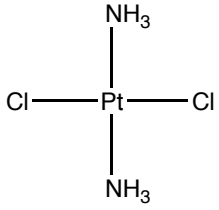
- Consider the complexes *cis*-$[PtCl_2(NH_3)_2]$ and *trans*-$[PtCl_2(NH_3)_2]$. Draw the structures of the two isomers, clearly illustrating the stereochemistry.

3

The platinum is bonded to four ligands (2 × Cl^- and 2 × NH_3). With four ligands, two geometries are possible – tetrahedral and square planar. Of these, only square planar gives rise to *cis* and *trans*-isomers and so the complexes must be square planar:



cis-diamminedichloridoplatinum(II)



trans-diamminedichloridoplatinum(II)

Briefly suggest why *cis*-$[PtCl_2(NH_3)_2]$ is an effective anti-cancer drug, but *trans*-$[PtCl_2(NH_3)_2]$ is not.

cis-$[PtCl_2(NH_3)_2]$ is believed to act by binding the _cis_-$Pt(NH_3)_2$ group to two nearby nitrogen atoms on the bases of a strand of DNA. This can only be achieved by the _cis_ isomer – the _trans_ form has 180° between the vacant sites of the $Pt(NH_3)_2$ group and is not able to bind in this way.

The coordination of the platinum to the DNA causes a kink in the α-helix of the DNA and this prevents its replication.

Marks 5

- Buffers made of mixtures of $H_2PO_4^-$ and HPO_4^{2-} are used to control the pH of soft drinks. What is the pH of a 350 mL drink containing 6.0 g of NaH_2PO_4 and 4.0 g of Na_2HPO_4?

  For phosphoric acid, H_3PO_4, $pK_{a1} = 2.15$, $pK_{a2} = 7.20$ and $pK_{a3} = 12.38$.

The formula masses of NaH_2PO_4 and Na_2HPO_4 are:

$$M(NaH_2PO_4) = (22.99\ (Na) + 2\times1.008\ (H) + 30.97\ (P) + 4\times16.00\ (O))\ g\ mol^{-1} = 119.976\ g\ mol^{-1}$$

$$M(Na_2HPO_4) = (2\times22.99\ (Na) + 1.008\ (H) + 30.97\ (P) + 4\times16.00\ (O))\ g\ mol^{-1} = 141.958\ g\ mol^{-1}$$

Hence, the number of moles of each present are:

$$n(NaH_2PO_4) = \text{mass / formula mass} = 6.0\ g / 119.976\ g\ mol^{-1} = 0.050\ mol$$

$$n(Na_2HPO_4) = 4.0 / 141.958\ g\ mol^{-1} = 0.028\ mol$$

As both are present in the same solution, the ratio of their concentrations is the same as the ratio of these amounts. There is no need to calculate the concentrations, although it does not change the answer.

The relevant equilibrium for this buffer is

$$H_2PO_4^-(aq) \rightleftharpoons HPO_4^{2-}(aq) + H^+(aq)$$

This corresponds to the second ionization of H_3PO_4 so pK_{a2} is used with the base acid being $H_2PO_4^-$ (from NaH_2PO_4) and the base being HPO_4^{2-} (from Na_2HPO_4). The pH can be calculated using the Henderson-Hasselbalch equation:

$$pH = pK_a + \log([base]/[acid])$$
$$= pK_{a2} + \log([HPO_4^{2-}]/[H_2PO_4^-]) = 7.20 + \log(0.028/0.050) = 6.95$$

Briefly describe how this buffer system functions. Use equations where appropriate.

The buffer contains an acid ($H_2PO_4^-$) and its conjugate base (HPO_4^{2-}) and is able to resist changes in pH when H^+ or OH^- is added.

If H^+ is added, the base reacts with it to remove it according to the equilibrium:

$$HPO_4^{2-}(aq) + H^+(aq) \rightleftharpoons H_2PO_4^-(aq)$$

ANSWER CONTINUES ON THE NEXT PAGE

If OH^- is added, the acid reacts with it to remove it according to the equilibrium:

$$H_2PO_4^-(aq) + OH^-(aq) \rightleftharpoons HPO_4^-(aq) + H_2O(l)$$

As long the amounts of the acid and base present are not exceeded, the changes in pH will be small.

Is this buffer better able to resist changes in pH following the addition of acid or of base? Explain your answer.

Maximum buffering occurs when equal amounts of base and acid are present. This buffer has less base than acid present. As a result, it is less able to resist cope with the addition of H^+.

Larger changes in pH result from the addition of acid.

Marks 3

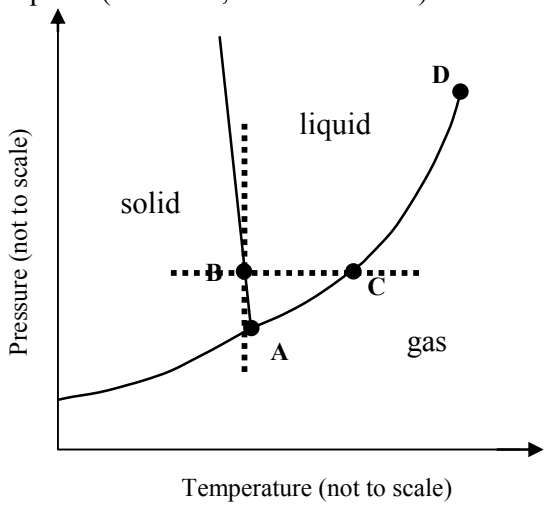
- The figure below illustrates the phase diagram for water. The points on the diagram correspond to:

  A: Triple point (0.0098 °C, 0.610 kPa)

  B: Normal melting point (0 °C, 1.01×10^2 kPa)

  C: Normal boiling point (100 °C, 1.01×10^2 kPa)

  D: Critical point (374.4 °C, 2.18×10^4 kPa)



Describe all of the phase changes that occur when water at 1.01×10^2 kPa is slowly warmed from –20 °C to 200 °C.

The horizontal dotted line on the phase diagram shows the changes. The pressure (1.01×10^2 kPa) corresponds to atmosphere or normal pressure.

The initial temperature of -20 °C is below the normal melting point so the water is initially a solid. As it warms up, it passes through the normal melting point (B, 0 °C) where melting to liquid occurs. After further warming, it passes through the normal boiling point (C, 100 °C). At this point it boils and a gas is formed.

Describe all of the phase changes that occur when water at 0 °C is slowly compressed from 0.500 kPa to 1000 kPa.

The vertical dotted line on the phase diagram shows the changes.

The temperature is below that of the triple point (A) as is the initial pressure (0.500 kPa). The water is initially a gas.

Increasing the pressure leads to water depositing straight from gas to solid. It does not pass through the liquid form or the triple point as the temperature and pressure are lower than at the triple point.

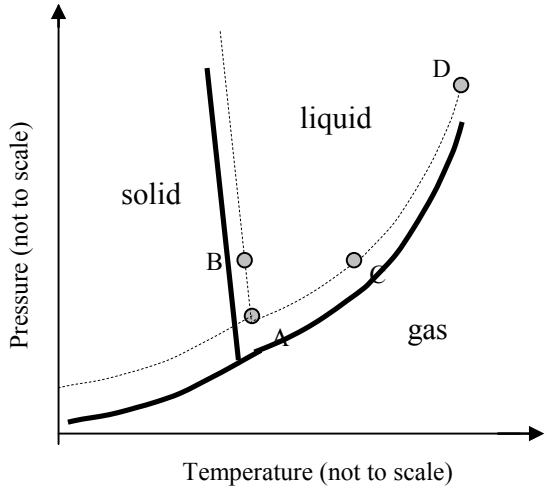
However, increasing the pressure further leads to melting of the solid to form a liquid, through the normal melting point (B).

Addition of salt to water raises its boiling point and lowers its melting point. Sketch the phase diagram for water containing salt, showing how it relates to the phase diagram for water (shown as dotted lines below).

Marks 3

The melting point is lowered so the solid – liquid boundary is shifted to lower temperature.

The boiling point is raised so the liquid – gas boundary is shifted to higher temperature.



In terms of the relative entropies of all relevant species, explain why the boiling point of salt water is higher than that of pure water.

Boiling water leads to a large increase in its entropy: $\Delta_{sys}S > 0$.

Because boiling requires breaking bonds, it is endothermic and requires energy from the surroundings. This lowers the entropy of the surroundings: $\Delta_{surr}S < 0$.

The boiling $\Delta_{univ}S$ to be positive. The boiling point is the temperature at which the gain in the entropy of the water is larger than the loss in the entropy of the surroundings.

When salt water is boiled, the $Na^+(aq)$ and $Cl^-(aq)$ ions form NaCl(s). This greatly reduces their entropy. Hence, when salt water boils the entropy gain is much smaller than when pure water boils.

Because $\Delta_{sys}S$ is less positive for boiling salt water, a *higher* temperature is required before it is larger than the loss in the entropy of the surroundings.

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks 2

- The following data were obtained for the reaction between gaseous nitric oxide and chlorine at –10 °C:

$$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$$

Experiment Number	Initial P_{NO} (atm)	Initial P_{Cl_2} (atm)	Initial Reaction Rate (atm s^{-1})
1	2.16	2.16	0.065
2	2.16	4.32	0.130
3	4.32	4.32	0.518

Derive an expression for the rate law for this reaction and calculate the value of the rate constant.

Between experiments (1) and (2), the partial pressure of NO is kept constant and the partial pressure of Cl_2 is doubled. This leads to a doubling of the rate so the reaction is first order with respect to Cl_2.

Between experiments (2) and (3), the partial pressure of Cl_2 is kept constant and the partial pressure of NO is doubled. This leads to the rate quadrupling. The reaction is second order with respect to NO.

Overall,

rate = $kP_{NO}^2 P_{Cl_2}$ or rate = $k'[NO(g)]^2[Cl_2(g)]$

As the partial pressure is proportional to the concentration. Either form is acceptable.

Using experiment (1), rate = 0.065 atm s^{-1} when P_{NO} = 2.16 atm and P_{Cl_2} = 2.16 atm. Hence,

0.065 atm s^{-1} = k × (2.16 atm)^2 × (2.16 atm)

k = 0.0064 atm^{-2} s^{-1}

The units of k are obtained by ensuring that those in the equation balance:

atm s^{-1} = (units of k) × (atm)^2 × (atm) so k has units of atm^{-2} s^{-1}.

Rate law: **rate = $kP_{NO}^2 P_{Cl_2}$ or rate = $k'[NO(g)]^2[Cl_2(g)]$**

Rate constant: **k = 0.0064 atm^{-2} s^{-1}**

Marks 4

The mechanism for this reaction has been postulated to be that below.

$2NO(g) \rightleftharpoons N_2O_2(g)$ fast

$N_2O_2(g) + Cl_2 \rightarrow 2NOCl(g)$ slow

Work out the rate law expected for this mechanism and hence show that it is consistent with the experimental rate law and the chemical equation.

The rate determining step is the slow, second step. As this is an elementary step, its rate law can be written down from its stoichiometry:

$$\text{rate} = k_2[N_2O_2(g)][Cl_2(g)]$$

where k_2 is the rate constant for this step.

This rate law involves the reactive intermediate N_2O_2. The concentration of this cannot be controlled so this rate law cannot be experimentally tested.

The first reaction is a fast equilibrium. The rate laws for the forward and backward elementary reactions are:

$$\text{rate of forward reaction} = k_1[NO(g)]^2$$
$$\text{rate of backward reaction} = k_{-1}[N_2O_2(g)]$$

where k_1 and k_{-1} are the rate constants for the forward and backward reactions, respectively.

At equilibrium, the rate of the forward and backward reactions are equal so

$$k_1[NO(g)]^2 = k_{-1}[N_2O_2(g)]$$

$$[N_2O_2(g)] = \frac{k_1}{k_{-1}}[NO(g)]^2 \quad \text{and} \quad \frac{[N_2O_2(g)]}{[NO(g)]^2} = \frac{k_1}{k_{-1}} = K_c$$

Substituting this value into the rate law for the second step gives,

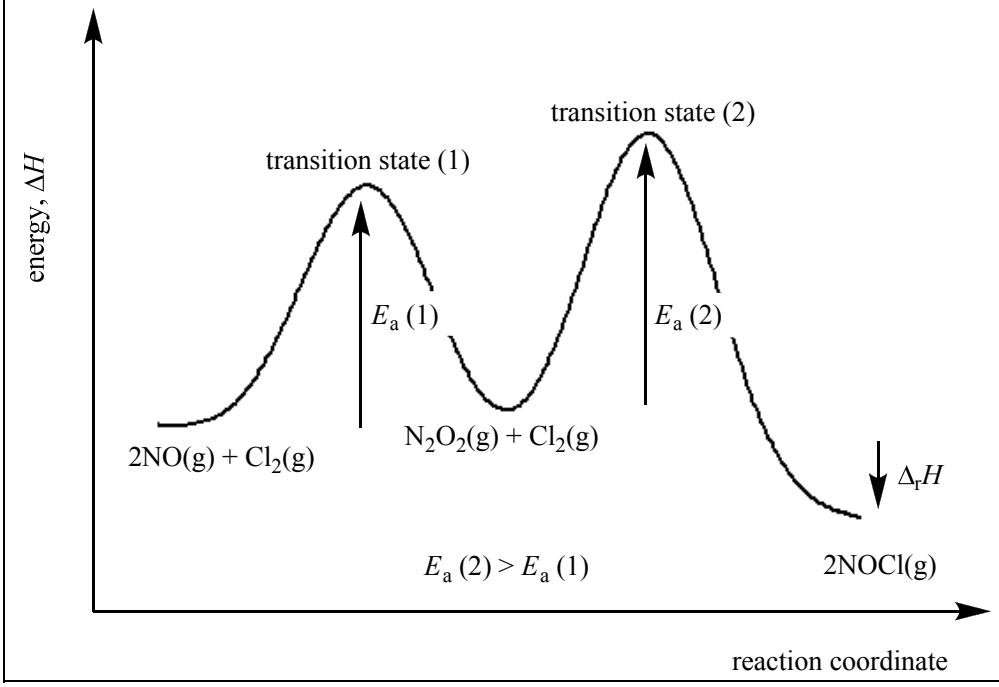
$$\text{rate} = k_2[N_2O_2(g)][Cl_2(g)]$$
$$= k_2\frac{k_1}{k_{-1}}[NO(g)]^2[Cl_2(g)] = k'[NO(g)]^2[Cl_2(g)] \quad \text{with } k' = k_2\frac{k_1}{k_{-1}} = k_2K_c$$

This rate law is second order with respect to NO and first order with respect to Cl_2, just as in the experimentally determined rate law in 2008-N-8. The proposed mechanism is thus consistent with the experiment.

ANSWER CONTINUES ON THE NEXT PAGE

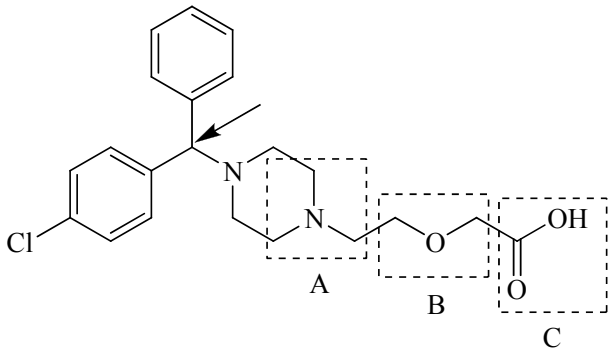
The reaction is exothermic. Draw the potential energy *vs* reaction coordinate diagram for this mechanism, labelling all species that can be isolated.

The second step is the rate determining step so it has the larger activation energy. The reaction is exothermic so the products have lower enthalpy than the reactants.



Marks 5

- The structure of the antihistamine, Zyrtec™, is given below.

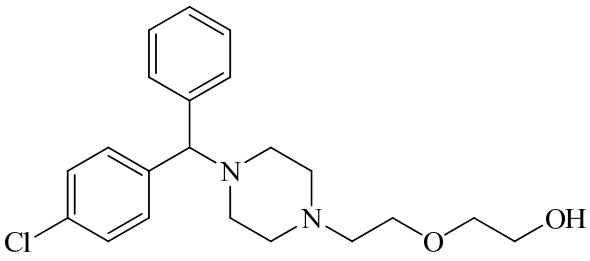


What is the name of the functional group in Box A?	**Amine (tertiary)**
What is the name of the functional group in Box B?	**Ether**
What is the name of the functional group in Box C?	**Carboxylic acid**

By drawing an arrow on the structure above, clearly indicate the stereocentre in the structure of Zyrtec.

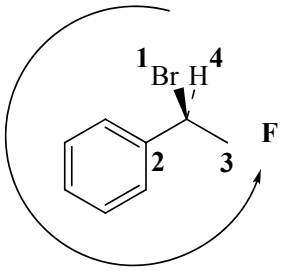
Draw the product of the reaction when Zyrtec is treated with $LiAlH_4$ followed by dilute acid.

$LiAlH_4$ will reduce the carboxylic acid all the way to an alcohol.



Marks 8

- Consider compound **F** shown below.

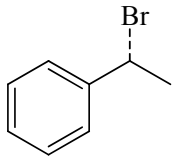


Assign the stereocentre in compound **F** as (*R*) or (*S*), explaining your reasoning.

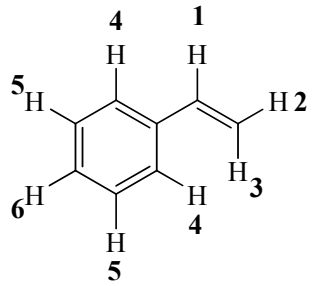
The priority of the groups around the stereocentre in F is shown above. Br has the highest atomic number and has the highest priority. H has the lowest atomic number and has the lowest priority. It is placed at the back. The other two groups both have carbon bonded to the stereocentre but the group on the left has a higher priority as it has C atoms attached whereas the group on the right has H atoms attached.

With the H atom at the back, the groups are arranged anti-clockwise and so the stereocentre is assigned as (*S*).

Draw the enantiomer of compound **F**.



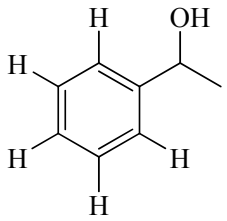
When compound **F** is reacted with hot KOH solution, a product (**G**) is formed that shows three peaks in the ^{1}H NMR spectrum in the region 7-8 ppm and three peaks in the region 5-6 ppm. Draw the structure of this product.



The signals due to H atoms 1, 2 and 3 are all different and occur in the region 5-6 ppm. The signals due to the aromatic H atoms appear in the 7-8 ppm region and are due to the groups 4, 5 and 6.

ANSWER CONTINUES ON THE PAGE

When **G** is reacted with dilute sulfuric acid, a further product, **H**, is formed. **H** has a peak at 3300 cm^{-1} in its IR spectrum. Draw the structure of product **H**.

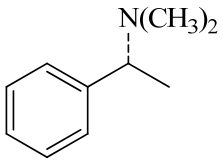


Markovnikov addition of H-OH across double bond, with OH adding to more substituted end of double bond. IR peak at 3300 cm^{-1} is due to O-H stretch.

Is **H** formed as a single enantiomer, as a racemate, or is **H** achiral?

The alcohol C is stereocentre but the addition reaction generates equal amounts of both enantiomers: a racemic mixture is formed.

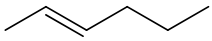
Assuming an S_N2 mechanism, draw the product of the substitution reaction between **F** and $(CH_3)_2NH$, indicating stereochemistry where appropriate.



The S_N2 reaction involves attack from the back, leading to inversion of the stereochemistry.

Marks 5

- Consider the compound **J** below.



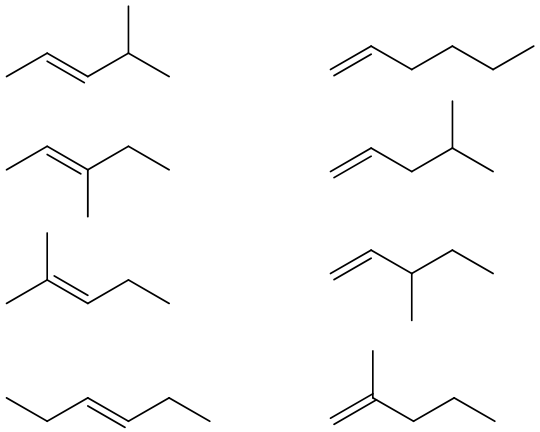
J

What is the systematic name for compound **J**.

(*E*)-hex-2-ene

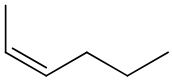
Draw a constitutional isomer of **J**.

Constitutional isomers have different atomic connectivities. Possible constitutional isomers include those below:



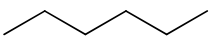
Draw a configurational isomer of **J**.

Configurational isomers have the same atomic connectivity but different spatial arrangements of the atoms. Because of the restricted rotation about a C=C double bond, the following compound is a configurational isomer of J:



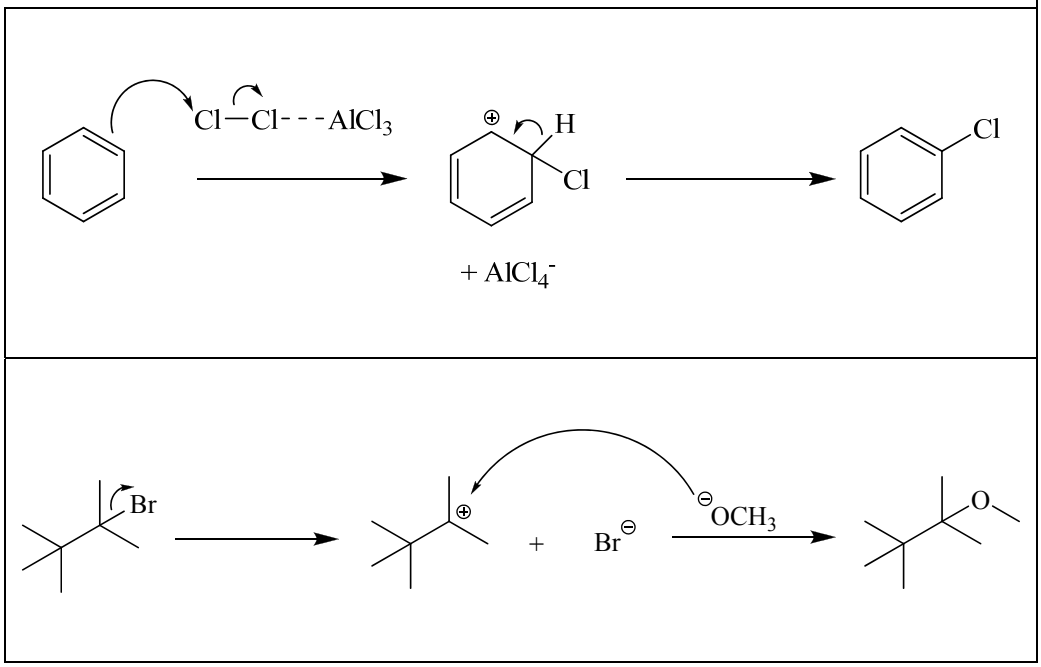
Draw the structure of the product formed when compound **J** is reacted with hydrogen gas (H_2) and a palladium on carbon (Pd/C) catalyst.

Treatment with H_2 a Pd/C catalyst will lead to addition of H-H across the C=C bond:



Marks 5

- Complete the following mechanism by adding curly arrows to illustrate the bonding changes that take place.

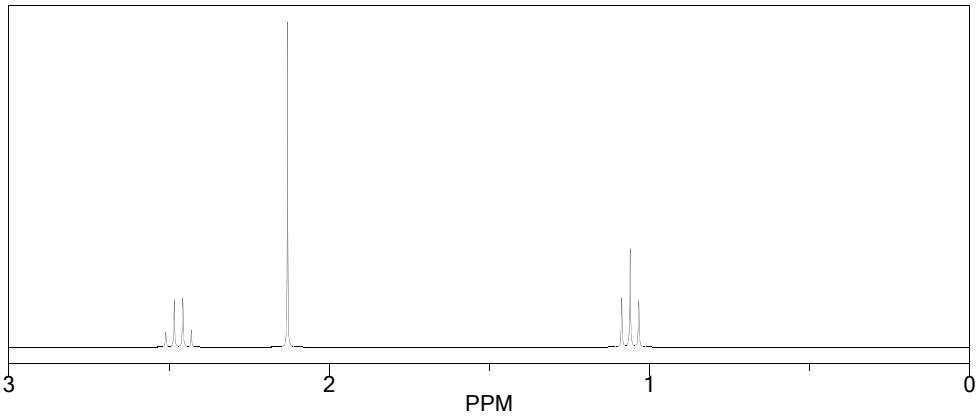


THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks 5

- An unknown compound **K** with the molecular formula C_4H_8O gives the following spectroscopic data.

  ^{1}H NMR: 1.06 ppm, triplet, integration = 3H
  2.13 ppm, singlet, integration = 3H
  2.47 ppm, quartet, integration = 2H



IR spectroscopy: stretch at 1715 cm^{-1}.

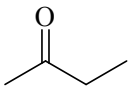
Use the information above to deduce the structure of compound **K**. Give reasoning for the structure chosen.

From the NMR:

- **the singlet at 2.13 ppm corresponds to 3H so is CH_3 group with no H on the neighbouring atom**
- **the triplet at 1.06 corresponds to 3H so is a CH_3 group with (n + 1) = 3 so n = 2 H atoms on the neighbouring atom**
- **the quartet at 2.47 ppm corresponds to 2H so is a CH_2 group with (n + 1) = 3 H on the neighbouring atom**
- **the triplet and the quartet together must therefore come from a CH_2CH_3 group.**

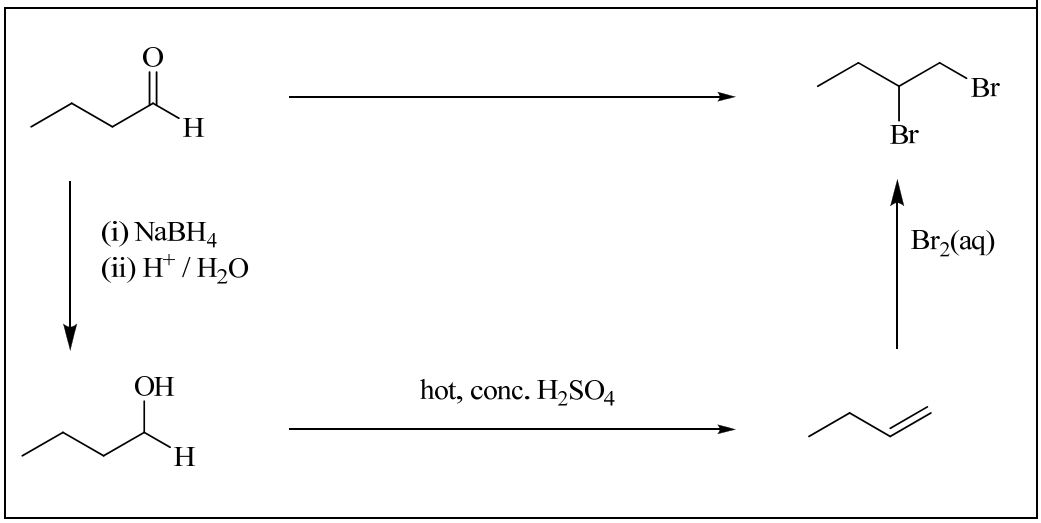
Absorbance in IR at 1715 cm^{-1} is typical of C=O group.

Molecular formula of C_4H_8O is sum of these three groups, so structure is:



Marks 5

- Devise a synthesis of 1,2-dibromobutane from butanal. Provide any intermediate structures and reagents. (Hint: More than one step is required.)



THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.