Topics in the June 2013 Exam Paper for CHEM1611

Click on the links for resources on each topic.

2013-J-2:

- Atomic Structure
- Chemical Bonding

2013-J-3:

- Chemical Bonding

2013-J-4:

- Chemical Bonding
- The Shapes of Molecules

2013-J-5:

- Atomic Structure

2013-J-6:

- Alkenes
- Alcohols, Phenols, Ethers and Thiols
- Carboxylic Acids and Derivatives
- Amines

2013-J-7:

- Introduction to Organic Chemistry
- Stereochemistry

2013-J-8:

- Alkenes
- Alcohols, Phenols, Ethers and Thiols
- Carboxylic Acids and Derivatives

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- Carbohydrates

2013-J-10:

- Amino Acids, Peptides and Proteins

2013-J-11:

- Amino Acids, Peptides and Proteins

2013-J-12:

- DNA and Nucleic Acids

- In the spaces provided, briefly explain the meaning of the following terms.

Marks
4

Effective nuclear charge

The force of attraction experienced by the outer electrons of an atom. It's a combination of the magnitude of the nuclear charge mitigated by shielding by the inner electrons. Effective nuclear charge increases to the top right of the periodic table.

Atomic emission spectrum

Unique for each element, the spectrum represents emission of light of disctrete frequencies corresponding to the energy differences between electron energy levels in an atom.. It results from the movement of electrons from a higher energy level to a lower one.

Ionic bonding

The electrostatic attraction between cations and anions. It is long range and non-directional and depends on the magnitude of the charges and the sizes of the ions. Typical of bonding between a group 1 or 2 metal with a group 16 or 17 non-metal.

Core electrons

Inner shell electrons that are not involved in bonding.

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks

- Silicon and carbon are both in Group 14 and form dioxides. Carbon dioxide is a gas at room temperature while silicon dioxide (sand) is a solid with a high melting point. Describe the bonding in these two materials and explain the differences in properties they show. **3**

CO_2 contains discrete molecules. Carbon makes four bonds by making two C=O double bonds. The C=O double bonds have strong σ and π components. Although these bonds are quite polar, these molecules are linear and do not possess dipole moments. Only very weak dispersion intermolecular forces hold the molecules together and CO_2 is a gas at room temperature.

SiO_2 is a network covalent solid. Each silicon makes four bonds by making four Si-O single bonds. The covalent network leads to a very strongly bonded solid with a very high melting point.

- Complete the following nuclear equations by filling in the missing particle. **2**

$${}^{14}_{7}N + {}^{1}_{1}p \rightarrow {}^{11}_{6}C + \boxed{{}^{4}_{2}He}$$

$${}^{11}_{6}C \rightarrow \boxed{{}^{11}_{5}B} + {}^{0}_{1}e^{+}$$

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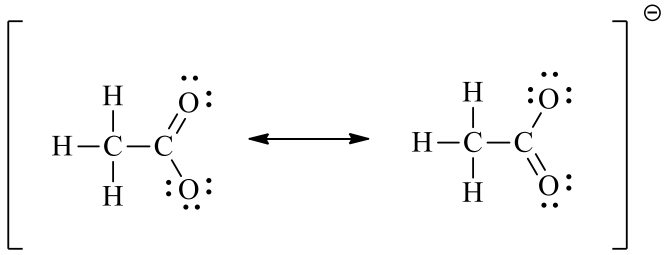
Marks 10

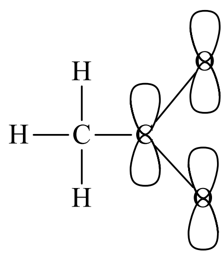
- Draw the Lewis structure of the acetate ion (CH_3COO^-) showing all appropriate resonance structures.



Indicate the hybridisation, molecular geometry and approximate bond angle about each of the carbon atoms in the acetate ion.

	$-CH_3$	$-COO^-$
Hybridisation of C	***sp*^{3}**	***sp*^{2}**
Molecular geometry about C	**tetrahedral**	**trigonal planar**
Approximate bond angles about C	**109°**	**120°**

The actual structure of the acetate ion is a weighted combination of all resonance structures. Sketch the σ-bond framework of the acetate ion and indicate the *p*-orbitals that are involved in the π-bonding of the acetate ion.



How many electrons are involved with the π-bonding? **4**

What is the hybridisation of the oxygen atoms in the acetate ion? ***sp*^{2}**

Marks
5

- The yellow light emitted from an excited sodium atom has a wavelength of 590 nm. What is the energy of one photon of this light and one mole of photons? Specify appropriate units with your answers.

The energy of a photon is related to its wavelength through Planck's equation:

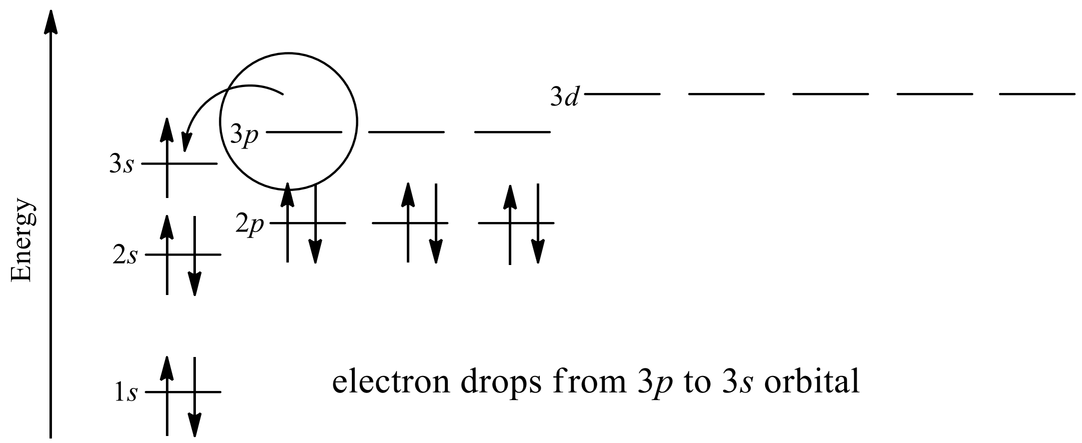
$$\begin{aligned} E &= hc / \lambda \\ &= (6.626 \times 10^{-34}\ \text{J s}) \times (2.998 \times 10^{8}\ \text{m s}^{-1}) / (590 \times 10^{-9}\ \text{m}) \\ &= 3.4 \times 10^{-19}\ \text{J} \end{aligned}$$

The energy of 1 mol is therefore:

$$E = (3.4 \times 10^{-19}\ \text{J}) \times (6.022 \times 10^{23}\ \text{mol}^{-1}) = 200\ \text{kJ mol}^{-1}$$

Energy	of one photon: **3.4×10^{-19} J**	of 1 mol of photons: **200 kJ mol^{-1}**

The yellow light is associated with the longest wavelength transition as the atom returns to the ground state electron configuration. Fill in the following energy level diagram for sodium and indicate the transition associated with the emission of yellow light.



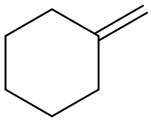
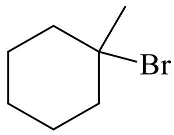
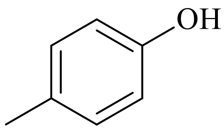
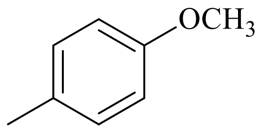
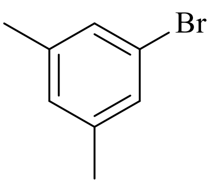
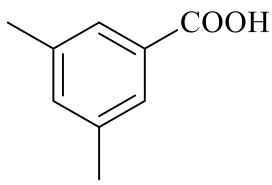
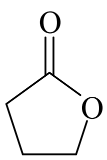
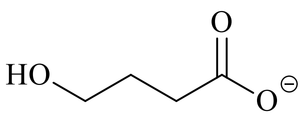
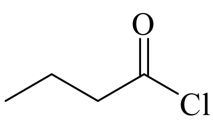
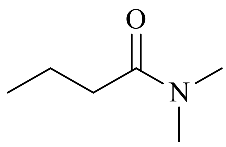
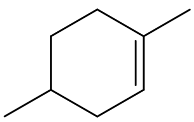
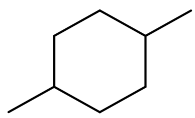
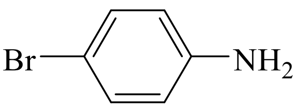
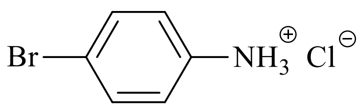
A quantum mechanical model of an atom can explain the emission spectrum of sodium, but the Bohr model of the atom cannot. Why?

A quantum mechanical model includes subshells, but a Bohr model does not. The yellow light is associated with electron movement between subshells.

The emission spectrum of sodium contains many more lines than would be predicted from Bohr's model.

- Complete the following table. Make sure you complete the name of the starting material where indicated.

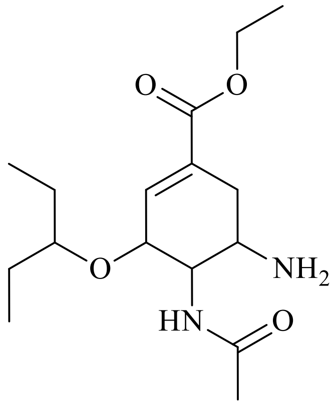
Marks 11

STARTING MATERIAL	REAGENTS/ CONDITIONS	CONSTITUTIONAL FORMULA(S) OF MAJOR ORGANIC PRODUCT(S)
	HBr / CCl_4 (solvent)	
 **Name: *p*-cresol or 4-methylphenol**	**1. NaOH** **2. CH_3I**	
	1. Mg / dry ether 2. CO_2 3. $H^{\oplus}$ / H_2O	
	3 M NaOH	
	excess $(CH_3)_2NH$	 + $(CH_3)_2N$
 **Name: 1,4-dimethylcyclohexene**	H_2 Pd/C catalyst	
	2 M HCl	

Marks
6

- Oseltamivir, marketed under the trade name Tamiflu, is an antiviral drug, which may slow the spread of influenza (flu) virus between cells in the body by stopping the virus from chemically cutting ties with its host cell.

Tamiflu



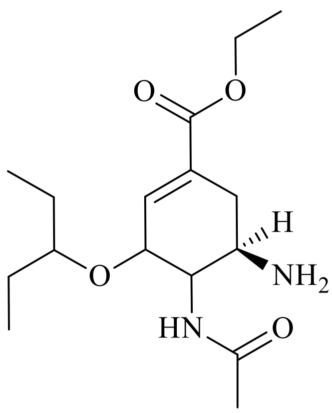
Give the molecular formula of Tamiflu. **$C_{16}H_{28}N_2O_4$**

List the functional groups present in Tamiflu.

alkene, amide, ester, ether, primary amine

How many stereogenic centres are there in Tamiflu?	**3**
How many possible stereoisomers can exist for Tamiflu?	**8**

Add the NH_2 and H groups to the stereogenic centre indicated below to give the (*R*)-configuration of that centre.



- Show clearly the reagents you would use to carry out the following chemical conversions. Note that more than one step is required and you should indicate all necessary steps and the constitutional formulas of any intermediate compounds.

Marks
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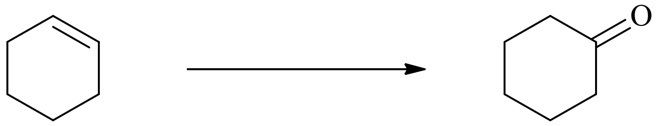
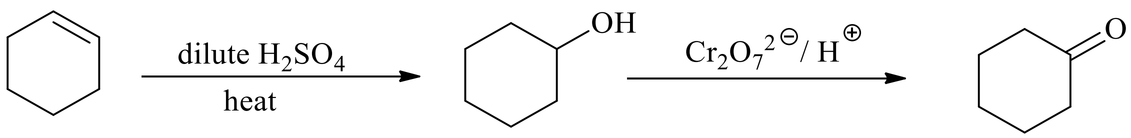
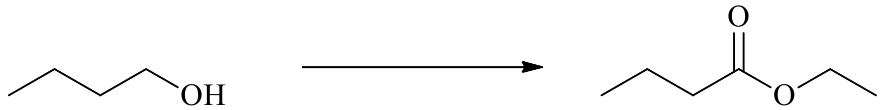
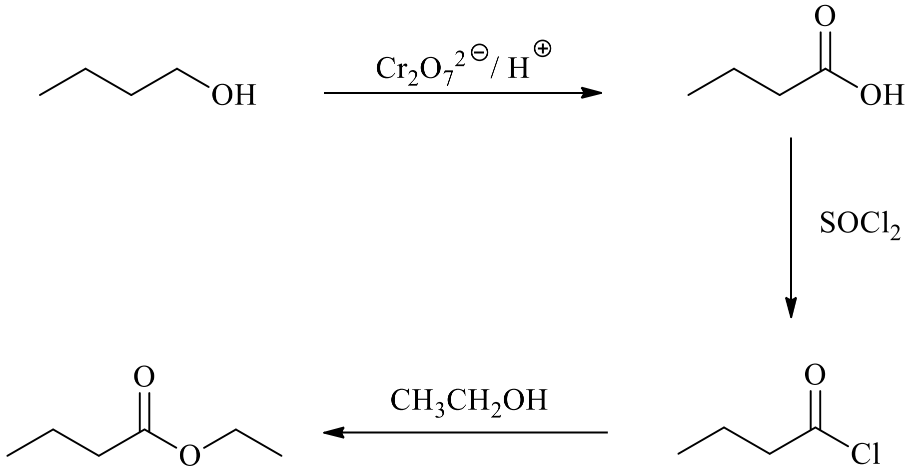


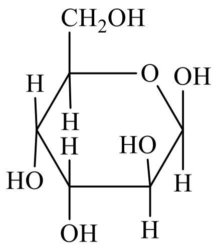




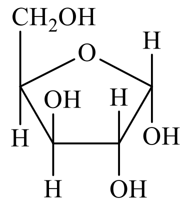


Marks 6

- Consider the following two monosaccharides, (**A**) and (**B**).



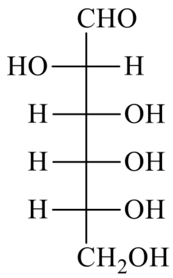
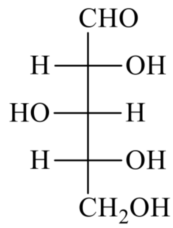
(**A**)



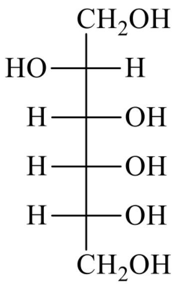
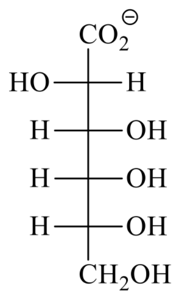
(**B**)

β-D-altropyranose α-D-xylofuranose

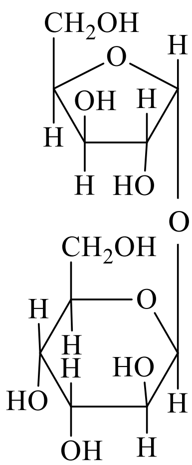
Draw Fischer projections of the open chain forms of (**A**) and (**B**).

(**A**)	(**B**)
	

Draw the major organic product of the reaction of D-altropyranose with the following reagents.

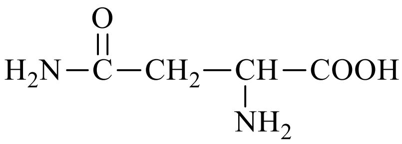
1. $NaBH_4$ 2. $H^{\oplus}$ / H_2O	$[Ag(NH_3)_2]^{\oplus}$ / $OH^{\ominus}$
	

Draw the Haworth stereoformula of a non-reducing disaccharide formed from (**A**) and (**B**).

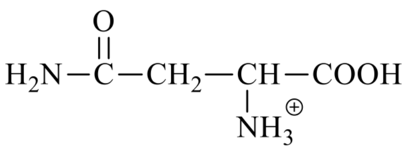
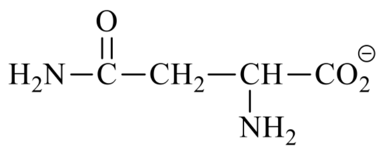
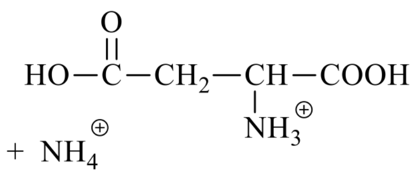
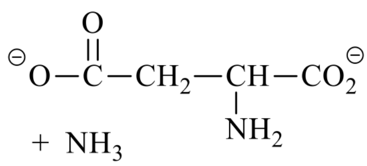


Marks 6

- The amino acid, asparagine, was isolated from asparagus juice in 1806. The uncharged form, **Y**, is given below.



Draw the constitutional formula of the product(s) formed in the reaction of **Y** with the following reagents.

Cold, dilute hydrochloric acid 	Cold, dilute sodium hydroxide 
Hot, 6 M hydrochloric acid 	Hot, 6 M sodium hydroxide 

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Marks
6

- Alanine (R = CH_3) and lysine (R = $CH_2CH_2CH_2CH_2NH_2$) are two common amino acids. Using *ala* and *lys* to represent the two amino acids, represent all constitutional isomers of the tripeptide formed from one *ala* and two *lys* units.

ala-lys-lys **lys-ala-lys** **lys-lys-ala**

Comment, giving your reason(s), on whether the tripeptide(s) will be acidic, neutral or basic in character.

The alanine side chain is neutral whilst the lysine side chain is basic. The tripeptide will therefore be basic.

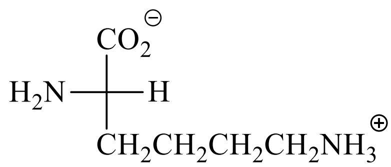
The pK_a values of lysine are 1.82 (α-COOH), 8.95 (α-$NH_3^{\oplus}$) and 10.53 (side chain). What is the value of the isoelectric point of lysine?

Fully protonated, lysine has a –COOH group and two NH_3^+ groups. It has a +2 charge. To get a neutral form, both =NH_3^+ groups must be deprotonated. The isoelectric point is thus the mean of the pK_a values for these two groups:

pI = ½ (8.95 + 10.53) = 9.74

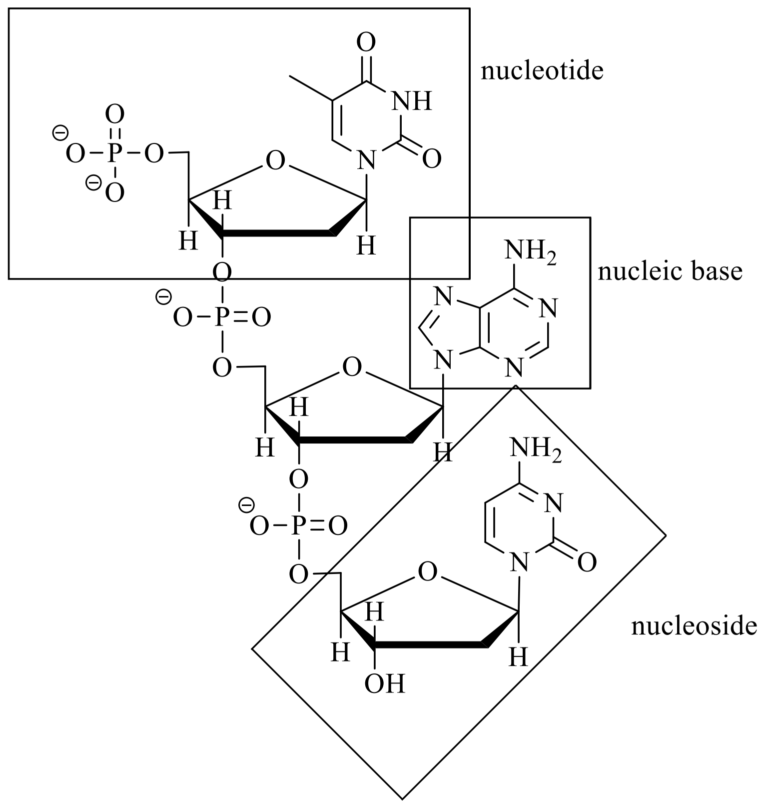
pI = **9.74**

Draw the Fischer projection of the zwitterionic form of lysine.



Marks
5

- Consider the following structure.



Is it a fragment of DNA or RNA? Give two reasons.

It is a DNA fragment:

- **The sugar is deoxyribose (RNA has ribose as the sugar).**
- **The topmost nucleic base is thymine (RNA utilises uracil instead of thymine).**

Clearly identify on the above structure one example of each of the following subunits.

nucleic base **- see above**

nucleoside **- see above**

nucleotide **- see above**