Fundamentals Synthetic Chemistry

22CMA102

Semester 1 2022/23 Online Long-window Exam paper

This is an online long-window examination, meaning you have **23 hours** in which to complete and submit this paper. How you manage your time within the 23-hour window is up to you, but we expect you should only need to spend approximately **2 hours** working on it. If you have extra time or rest breaks as part of a Reasonable Adjustment, you will need to add this to the amount of time you are expected to spend on the paper.

It is your responsibility to submit your work by the deadline for this examination. You must make sure you leave yourself enough time to do so.

It is also your responsibility to check that you have submitted the correct file.

Exam Help

If you are experiencing difficulties in accessing or uploading files during the exam period, you should contact the Exam Helpline. For urgent queries please call **01509 222900**.

For other queries email examhelp@lboro.ac.uk

You may handwrite and/or word process your answers, as you see fit.

You may use a calculator for this exam.

Candidates may use their own Sigma Aldrich Cochrane Molecular Model Kits

Answer ALL Questions

1. (a) (i) Write the balanced equation for the reaction of sulfuric acid with water. [1 mark]

(ii) Calculate the pH of 0.075 mol dm^{-3} sulfuric acid solution in water, stating any assumptions you have made. [2 marks]

(iii) Calculate the mass of sulfuric acid in 250 cm^3 of the 0.0750 mol dm^{-3} solution. M_r of sulfuric acid = 98.079 g mol^{-1}. [2 marks]

(b) Magnesium reacts with hydrochloric acid to form magnesium chloride and hydrogen.

(i) Write a balanced equation for this reaction. [1 mark]

(ii) Magnesium chloride can, in turn, be crystallised out of this reaction mixture as the hexahydrate (general formula $M_aX_b{\cdot}nH_2O$ where M = metal ion, X = halogen, and a, b, and n are integers). What mass of magnesium chloride hexahydrate can be prepared from 3.45 g of magnesium metal and hydrochloric acid, assuming that the acid is in excess? As part of your answer, write down the chemical formula of magnesium chloride hexahydrate, and explain each step of your calculations.
AWs (g mol^{-1}): Mg = 24.3, Cl = 35.5, O = 16.0, H = 1.01 [4 marks]

2. (a) Sketch and label the bonding and antibonding molecular orbitals resulting from all the possible combinations of two p orbitals overlapping. [2 marks]

(b) Draw the molecular orbital diagram of NO^+ and complete this with the appropriate number of electrons and any appropriate labelling. [3 marks]

(c)

(i) Calculate the bond order of CO^{2-}. Is the molecule stable? Compare the bond length between CO^{2-} and CO. [4 marks]

(ii) The electronic configuration of Cu^{2+} is $[Ar]3d^9$. According to this electronic configuration, deduce if Cu^+ is paramagnetic or diamagnetic. $[Ar]=1s^2 2s^2 2p^6 3s^2 3p^6$ [3 marks]

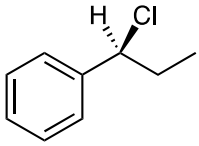
(d) Use VSEPR theory to deduce, step by step, the molecular geometry of SO_2, BrF_3 and $TeBr_2$. [3 marks]

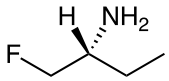
3. (a) Explain why the ionisation energies are so high for Noble gases and why they drop as you go down the group? [2 marks]

(b) Account for the following observation: Li form Li_2O while Na forms Na_2O_2 and Rb forms RbO_2 despite being in the same group? [3 marks]

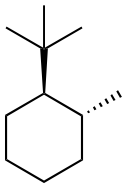
(c) Use Slater's Rules to calculate the effective nuclear charge felt by an outer electron in the Be, Mg, and Ca atoms. Compare your values with the values of corresponding ions of Be, Mg and Ca. Show and explain your workings. What conclusions can be drawn about the relative ionic radii compared to the atomic radii of the three elements? [10 marks]

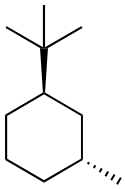
4. (a) Indicate the absolute configuration (*R* or *S*) of each stereocentre in the following compounds and explain your answer. [4 marks]



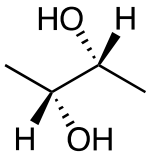


(b) Draw the most stable conformations of *trans* 1-tert-butyl-2-methylcyclohexane and *trans* 1-tert-butyl-3-methylcyclohexane, explaining your answer. [6 marks]





(c) Draw all possible stereoisomers of the compound below and specify how they are related. [6 marks]



(d) Indicate with the aid of a diagram the bonding in ethene (C_2H_4). You should mention the hybridization of the carbon atoms, as well as illustrating the shape and orientation of the orbitals. [4 marks]

5. *tert*-Butyl bromide (2-bromo-2-methyl propane) and methyl iodide are substrates for nucleophilic substitution reactions. Explain in detail which type of reaction each of these chemicals undergoes. You should mention the differences between the two reactions, paying particular attention to how the structure influences the reactivity. One of these substrates will also give an alternative product (i.e., not a nucleophilic substitution product). Describe in detail what this product is and how it arises. [12 marks]

[Dr. M. R. J. Elsegood, Dr. A. Fernandez-Mato, Dr. P. Goddard, Dr. M. C. Kimber]