New Zealand Chemistry Olympiad Trust

Training Group Selection Examination

Monday 2 November 2015

TIME ALLOWED: 120 minutes

Answer **ALL** questions on this examination booklet

Calculators may be used

The marks for the **eleven** (11) questions sum to **100**

A periodic table with atomic masses is also provided

STUDENT'S NAME:_____

STUDENT'S EMAIL:_____

SCHOOL:_____

Question	1	2	3	4	5	6	7	8	9	10	11	Total
	/5	/6	/7	/7	/6	/12	/12	/10	/11	14	/10	/100
Mark												

QUESTION ONE (5 marks)

Collision theory requires collisions to have

QUESTION TWO (6 marks)

The following colourless liquids are supplied in unlabeled bottles: octan-1-amine, octanoic acid, octane, distilled water, sodium carbonate solution, hydrochloric acid solution. Using just the unlabeled bottles and some empty test tubes, how could you determine which is which?

Systematically select each of the unknowns and mix a small sample with each of the other unknowns. Let's call them A, B, C, D, E and F.

One of the unknowns (let's call it A) will form bubbles with two other unknowns, this is sodium carbonate solution. The two other unknowns (let's call them B and C) are either hydrochloric acid or octanoic acid.

The sodium carbonate (A) will form two layers with octane and octan-1-amine (let's call them D and E) but will form one layer with the last unknown water (call it F).

Now look at the water sample (F) with B and C, the one the mixes is hydrochloric acid (let's call that B) while the one that forms two layers is octanoic acid (let's call it C).

Finally take two samples of HCl (B) and add a few drops of D and E and shake, the one that dissolves is octan-1-

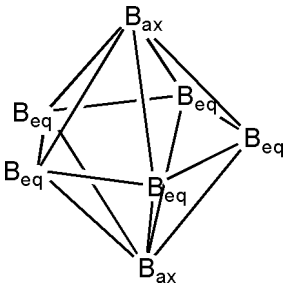
QUESTION FOUR (7 marks)

(a) Alkenes are known to form geometric (configurational) isomers. There are two requirements for this type of isomerism. Briefly explain why 1-chloropropene forms geometric isomers while 2-chloropropene does not.

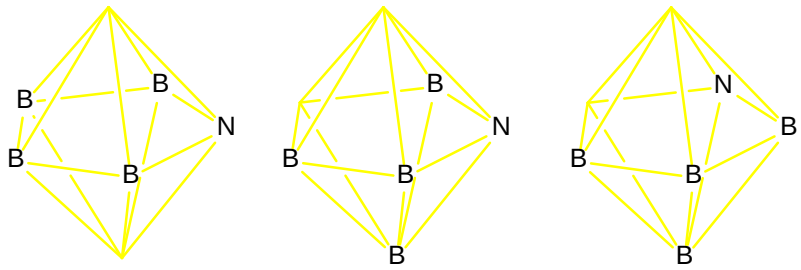
(Requirements: Restricted rotation and differing groups at multiple positions locked by restricted rotation)

QUESTION FIVE (6 marks)

$[B_7H_7]^{2-}$ is a **pentagonal bipyramid** (shown below without the H atoms) with ten triangular faces. It has two types of B atoms; two axial (ax) and five equatorial (eq). An arachno-**pentagonal bipyramid** is missing **two** of these vertices/atoms.



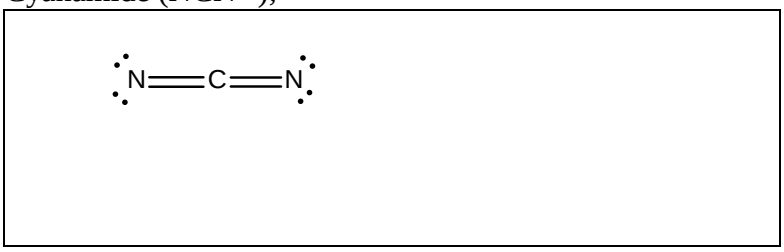
The cluster $[B_4NH_5]^{4-}$, in which one of the B atoms has been replaced by an N atom, is predicted to be an arachno-pentagonal bipyramid. Sketch the possible isomers for this ion by writing B or N over the appropriate vertices in the polyhedra given below. If both missing vertices are equatorial, they must be next to each other. You may not need to use all of the polyhedra to show all of the isomers.



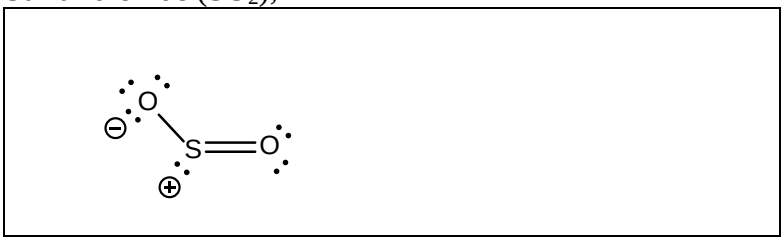
QUESTION SIX (12 marks)

(a) Draw ONE Lewis structure and the 3-dimensional molecular shape for each of the following triatomic species:

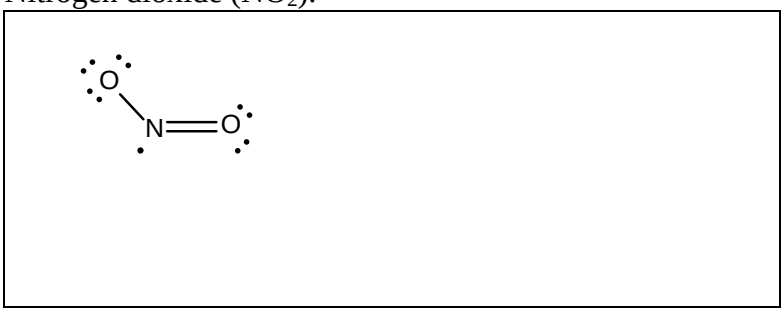
(i) Cyanamide (NCN^{2-});



(ii) Sulfur dioxide (SO_2);



(iii) Nitrogen dioxide (NO_2).

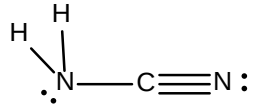


(iv) The "formal charge" is the number of valence electrons in the atom, minus the number of lone-pair electrons at that atom in the Lewis structure, minus the number of bonds to the atom in the Lewis structure. Formal charge can be used to help explain where electrons are likely to be found on atoms in a molecule. Write the formal charge on the atoms of SO_2 in your diagram in part (ii).

(b) List NCN^{2-}, SO_2 and NO_2 in order of increasing bond angle.

$SO_2 < NO_2 < NCN^{2-}$

(c) Addition of two equivalents of acid (2 protons) to cyanamide, NCN^{2-}, gives a product in which the two N atoms are different. Draw a Lewis structure for your proposed product.



QUESTION SEVEN (12 marks)

(a) Discuss the meaning of the term "electrochemical series". Arrange the elements calcium, copper, magnesium, potassium and zinc in an order which illustrates the series. Justify the order you give by considering the behaviour of these elements towards water (or steam).

The electrochemical series is a measure of the ease of oxidation of the metal when it reacts with water.
Decreasing ease of oxidation: potassium > calcium > magnesium > zinc > copper

- Potassium has only one valence electron which is further from the nucleus than in the other metals, so most easily oxidised.
- Calcium has the same valence shell as potassium but as a Group II element, with two valence electrons, which would therefore be less easily oxidised.
- Magnesium is also from Group II, but the two valence electrons are closer to the nucleus, so it is oxidised less easily than calcium.
- Zinc is less reactive towards water than magnesium
- Copper is a stable metal that is unreactive towards water, so will be least easily oxidised.

1 mark for order
3 marks for potassium, calcium and magnesium

(c) A student placed 0.20 mol of $PCl_3(g)$ and 0.10 mol of $Cl_2(g)$ into a 1.00 L flask at 250 ºC. The reaction $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$ was allowed to come to equilibrium, at which time it was found that the flask contained 0.12 mol of PCl_3.

(i) What were the initial concentrations of the reactants and product?

Since the total volume is 1.00 L, the concentrations will be numerically equal to the number of moles of the reactants and products.
$[PCl_3] = 0.20 \text{ mol } L^{-1}$
$[Cl_2] = 0.10 \text{ mol } L^{-1}$

(ii) What were the changes in concentration?

Since 0.12 moles of PCl_3 remained, the change in the number of moles will be 0.08 moles.
Since the stoichiometry is 1:1
The concentrations of the reactants will be reduced by 0.08 mol L^{-1} while the concetration of the product will increase by 0.08 mol L-1.
$[PCl_3]$ and $[Cl_2]$ will be **reduced by 0.08 mol L^{-1}** **½ mark**
$[PCl_5]$ will **increase by 0.08 mol L^{-1}** **½ mark**
1 mark

(iii) What were the equilibrium concentrations?

$[PCl_3] = 0.12 \text{ mol } L^{-1}$

$[Cl_2] = 0.02 \text{ mol } L^{-1}$

$[PCl_5] = 0.08 \text{ mol } L^{-1}$

1 ½ marks (½ mark each)

(iv) What is the value for K_c for this reaction?

$K_c = [PCl_5] / [PCl_3][Cl_2] = (0.08) / (0.12)(0.02) = 33.3 \text{ L mol}^{-1} = 33 \text{ l mol}^{-1}$ (2 S.F.)

1 mark

QUESTION NINE (11 marks)

(a) Outdoor flames, such as patio heaters and the Olympic flame, may contribute to global climate change due to the carbon dioxide produced from the combustion of hydrocarbons.

(iv) Calculate the rate at which propane must leave the cylinder (in $cm^3\ s^{-1}$) to produce 15 kW (i

QUESTION TEN

(c) Iodine forms the fluorides IF, IF_3, IF_5 and IF_7.

In these compounds the oxidation number of iodine is between 0 and +7. This means there is a possibility that a disproportionation reaction will occur to form the compound with iodine in its next highest oxidation number, and elemental iodine. For example, IF_3 might disproportionate to give IF_5 and I_2.

(i) Give balanced equations for

QUESTION ELEVEN (10 marks)

Nitrite ions can be determined quantitatively by titration with permanganate ions (MnO_4^-) in acidic solution, according to the equation: $2MnO_4^- + 5NO_2^- + 6H^+ \rightarrow 2Mn^{2+} + 3H_2O + 5NO_3^-$

(a) Write the two half equations for the overall reaction between permanganate ions and nitrite ions in acidic solution.

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ 1 mark

$NO_2^- + H$

PERIODIC TABLE OF THE ELEMENTS

1	2											13	14	15	16	17	18
						1 **H** 1.0											2 **He** 4.0
3 **Li** 6.9	4 **Be** 9.0											5 **B** 10.8	6 **C** 12.0	7 **N** 14.0	8 **O** 16.0	9 **F** 19.0	10 **Ne** 20.2
11 **Na** 23.0	12 **Mg** 24.3	3	4	5	6	7	8	9	10	11	12	13 **Al** 27.0	14 **Si** 28.1	15 **P** 31.0	16 **S** 32.1	17 **Cl** 35.5	18 **Ar** 40.0
19 **K** 39.1	20 **Ca** 40.1	21 **Sc** 45.0	22 **Ti** 47.9	23 **V** 50.9	24												