

New Zealand Chemistry Olympiad Trust

Training Group Selection Examination

Tuesday 4 November 2008

TIME ALLOWED: TWO (2) hours

Answer **ALL** questions on this examination booklet

Calculators may be used

The marks for the **twelve** (12) questions sum to **80**

A periodic table with atomic masses is attached

Name: _____

[illegible]

1. [8 marks]

1.060 g of Na_2CO_3 and 0.630 g of NaHCO_3 are dissolved in water and the solution made up to 250.0 mL in a volumetric flask. A 25.0 mL sample of the solution is titrated with 0.100 mol L^{-1} HCl using methyl orange as an indicator.

(a) Calculate the volume of HCl consumed at the end point.

(b) At 20°C and 1 bar pressure, the volume of 1 mole of a gas is 24.4 L. Calculate the volume of CO_2 (in mL) formed in the titration. Ignore the solubility of CO_2 in water.

2. [5 marks]

Commercial starch is made from corn. In the final stages of the process the starch contains 44% water. After drying, 73% of the original water has been removed. The resulting material is sold as pearl starch.

(a) Calculate the weight of water removed per kilogram of wet starch.

(b) Calculate the composition of the pearl starch.

3. [10 marks]

The table below shows the solubility of various ionic compounds:

	Ag^+	Ba^{2+}	K^+	Pb^{2+}
Cl^-	White precipitate	Colourless solution	Colourless solution	White precipitate
CrO_4^{2-}	Brown precipitate	Yellow precipitate	Yellow solution	Yellow precipitate
I^-	Yellow Precipitate	Colourless solution	Colourless solution	Yellow precipitate
NO_3^-	Colourless Solution	Colourless solution	Colourless solution	Colourless solution

You are provided with pure dilute solutions of AgNO_3 , BaCl_2 , K_2CrO_4 , KI , and $\text{Pb}(\text{NO}_3)_2$ in unmarked test tubes and a bottle of dilute sulphuric acid.

- (i) Mixing solutions of A with C gave a yellow precipitate.
- (ii) Mixing solutions of A and D also gave a yellow precipitate
- (iii) Mixing solutions of A and E gave a yellow solution which turns brown when sulphuric acid is added.
- (iv) Mixing B and C gave a white precipitate.
- (v) Mixing B and D also gave a white precipitate.
- (vi) Mixing C and E gave a brown precipitate.
- (vii) Mixing D and E gave a yellow precipitate.

(a) Identify solutions A – E.

(b) Write balanced **ionic** equations for the observed reactions in (i) to (vii)

4. [5 marks]

What species are present in significant quantities when the following solutions are mixed:

- (a) 25.0 mL of 0.100 mol L⁻¹ ethanoic acid (CH₃COOH) and 25.0 mL of 0.100 mol L⁻¹ NaOH.
- (b) 25.0 mL of 0.100 mol L⁻¹ ethanoic acid (CH₃COOH) and 15.0 mL of 0.100 mol L⁻¹ NaOH.
- (c) 25.0 mL of 0.100 mol L⁻¹ CuSO₄ and 25.0 mL of 0.100 mol L⁻¹ NH₃.
- (d) 25.0 mL of 0.100 mol L⁻¹ FeCl₃ and 15.0 mL of 0.100 mol L⁻¹ KI (note than an oxidation-reduction reaction occurs)
- (e) 25.0 mL of 0.100 mol L⁻¹ ZnSO₄ and 20.0 mL of 0.400 mol L⁻¹ NaOH

5. [5 marks]

Which of the following molecules are polar? If the molecule is polar, draw the molecular shape and indicate which end of the molecule is slightly positive.

- (a) SO₂
- (b) SO₃
- (c) PCl₃
- (d) BCl₃

6. [5 marks]

For each set of atoms/ions given below, circle the smallest:



7. [7 marks]

By considering the relevant half equations, write balanced equations for the following reactions:

(a) zinc metal decolourising copper(II) sulfate solution;

(b) chlorine water turning sodium bromide solution orange;

(c) magnesium ribbon reacting with dilute hydrochloric acid;

(d) manganese dioxide reacting with hydrochloric acid to produce a yellow-green gas and a solution of manganese(II) chloride;

- (e) sodium sulfite solution turning a solution of acidified potassium dichromate from orange to green;
- (f) acidified potassium permanganate reacting with a solution of iron(II) oxalate, FeC_2O_4 (the oxalate ion is oxidised to CO_2 while the Fe^{2+} ion is also oxidised).

8. [6 marks]

The atoms C, N, and O can be arranged in three different orders to form negative ions, i.e. CNO^- , CON^- and NCO^- . Salts of one of these are stable, salts of another are explosive, and the salts of another are unknown.

Choose any **TWO** and:

- (a) Write Lewis electron dot structures for each atomic arrangement (each atom obeys the octet rule).
- (b) For each atom in each structure, calculate the **formal charge** (i.e. the number of valence electrons in the atom, minus twice the number of lone pairs, minus the number of bonds to the atom).

9. [8 marks]

The strength of a bond between two atoms is closely related to the degree with which the bonding orbitals overlap and this largely depends on the bond length, however, strong interactions between lone pairs of electrons can weaken a bond.

- (a) Comment on the relative energies of the following bonds:
O–O (142 kJ/mol) < S–S (226 kJ/mol) > Se–Se (172 kJ/mol) > Te–Te (126 kJ/mol);
- (b) Explain why the C=C double bond strength (682 kJ/mol) such as in C₂H₄, is much stronger than the N=N double bond strength (450 kJ/mol) such as in N₂H₂;
- (c) Explain why the C≡C triple bond strength (962 kJ/mol), such as in C₂H₂, is similar to the N≡N triple bond strength (946 kJ/mol) in N₂.

10. [6 marks]

When 5.00 g of solid NH_4Cl is dissolved in 100.0 g of water, the temperature decreases by 3.30°C . The specific heat of water is $4.184 \text{ J g}^{-1} ^\circ\text{C}^{-1}$.

(a) Calculate the enthalpy change when one mole of $\text{NH}_4\text{Cl(s)}$ is dissolved in water to make one litre of solution. Assume the specific heat of the solution is the same as pure water.

(b) Calculate the temperature change when 8.00 g of NH_4Cl is dissolved in 250.0 mL of water

11. [7 marks]

Compound **A**, $\text{C}_5\text{H}_{12}\text{O}$, on treatment with concentrated sulfuric acid yields two compounds, **B** and **C**, each with molecular formula C_5H_{10} . Neither **B** nor **C** can exhibit geometric isomerism. Reaction of each of compounds **B** and **C** with HBr produce the same major product, compound **D**, $\text{C}_5\text{H}_{11}\text{Br}$.

Another compound **E** is a structural isomer of **A**. On treatment with concentrated sulfuric acid, compound **E** yields two compounds, **F** and **G**, with molecular formula C_5H_{10} . Only compound **F** can exhibit geometric isomerism.

Give the condensed structural formulae for **A** through **G** (you can use the back of the previous page for your answer if necessary).

12. [8 marks]

There are six different isomers with the formula $C_4H_8O_2$, each one containing a $-CO_2-$ group. When added to water, two of the six are much more soluble than the other four.

- (a) Write structural formulae for the two water-soluble compounds and explain why these two structures have a much greater solubility than the other four.
- (b) Draw structural formulae for two of the four less soluble isomers and give the systematic name for each of them.
- (c) Write an equation for the laboratory synthesis of one of these four less soluble isomers and name the two organic reactants.

Periodic Table

1 H 1.008																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.8	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.0	10 Ne 20.2
11 Na 23.0	12 Mg 24.3											13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.1	17 Cl 35.5	18 Ar 39.9
19 K 39.1	20 Ca 40.1	21 Sc 45.0	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.9	27 Co 58.9	28 Ni 58.7	29 Cu 63.5	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8
37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	43 Tc (99)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57-71 see below	72 Hf 178.5	73 Ta 181.0	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89-103 see below	104 Rf (257)	105 Db (260)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 	111 	112 						
			57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (147)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
			89 Ac (227)	90 Th 232.0	91 Pa (231)	92 U 238.1	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (245)	98 Cf (251)	99 Es (254)	100 Fm (253)	101 Md (256)	102 No (254)	103 Lr (257)