

New Zealand Chemistry Olympiad Trust

Training Group Selection Examination

Thursday 1 November 2007

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. [6 marks]

A compound consists of 14.29% carbon, 57.14% oxygen, 1.190% hydrogen and an element having the same number of moles as there are moles of carbon. Determine the formula of the compound.

2. [9 marks]

Cl_2 dissolves in water to give HOCl and HCl in equal amounts.
 HOCl decomposes on heating to give HClO_3 and HCl .
 HClO_3 (HOClO_2) is in turn unstable and decomposes to a variety of products.
One mode of decomposition gives HClO_4 (HOClO_3) and ClO_2 .

Using half equations for the oxidation and reduction reactions, write balanced equations for all of these redox reactions.

3. [6 marks]

Calculate the pH of the solution that results from mixing at 25° C

- a) 10 mL of 0.15 mol L⁻¹ NaOH with 25 mL of 0.10 mol L⁻¹ HCl
- b) 20 mL of 0.15 mol L⁻¹ NaOH with 25 mL of 0.10 mol L⁻¹ HCl

$$K_W = 1 \times 10^{-14}$$

4. [8 marks]

In an experiment excess copper powder was added to 100 mL of 0.50 mol L⁻¹ solution of silver nitrate, placed in a calorimeter with a heat capacity of 2000 J °C⁻¹. The temperature rose from 19.5°C to 20.9°C. The mass of excess Cu is assumed to be negligible and the specific heat capacity, *s*, of the silver nitrate solution is 4.2 J °C⁻¹ g⁻¹,

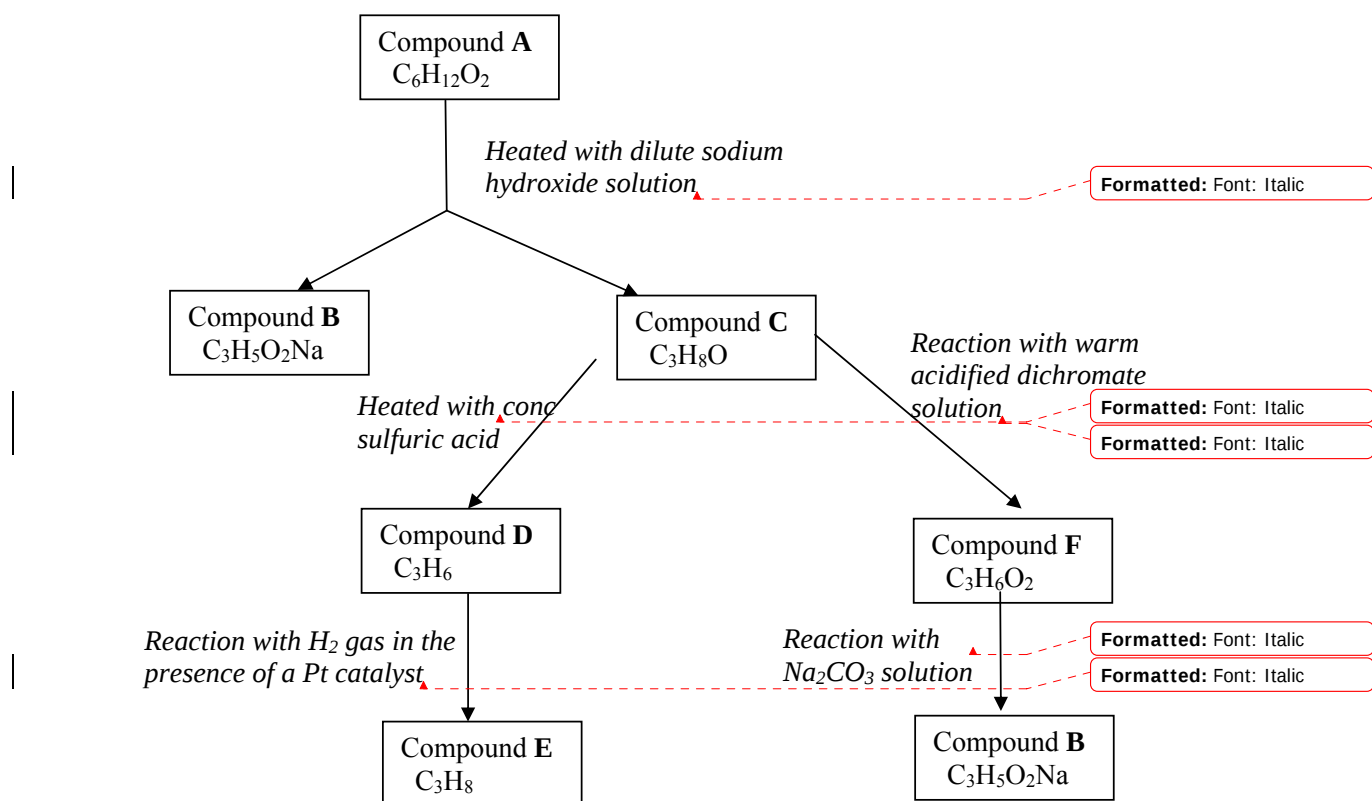
Write an equation for the reaction of copper with aqueous silver nitrate, and calculate the enthalpy change per mole of copper.

$$\text{Heat change } q = ms\Delta T$$

Assume 1 mL of solution weighs 1 g.

5. [6 marks]

- a) Draw structural formulae for compounds **A** to **F** in the reaction scheme below.



A

B

C

D

E

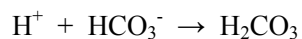
F

6. [7 marks]

When 'hard' water containing Ca^{2+} ions is passed through an ion exchange resin the Ca^{2+} ions displace H^+ ions from the column as follows:



HCO_3^- ions in the water react in the column with the H^+ ions that are generated as follows:

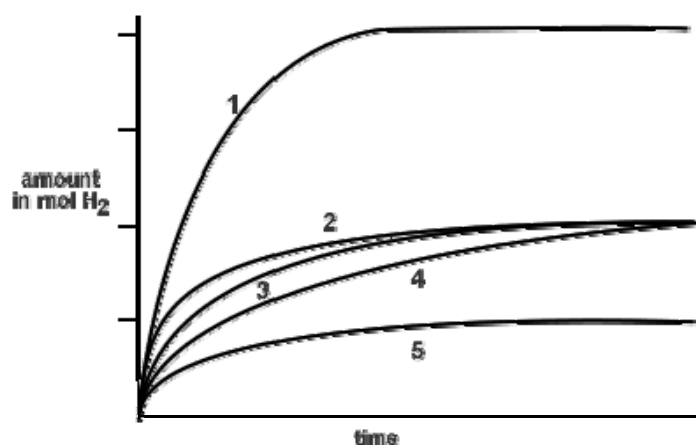


When 100 mL of water that has passed through the column is titrated with $0.0100 \text{ mol L}^{-1}$ NaOH, 5.00 mL are required to reach an end point.

When 100 mL of the original sample is titrated with $0.0100 \text{ mol L}^{-1}$ HCl, 10.00 mL are required to reach an end point.

Calculate the concentration of Ca^{2+} in the water sample in (i) mol L^{-1} , and (ii) ppm (equivalent to mg/L).

7. [10 marks]



The curves above are obtained by reacting excess zinc with the solutions of hydrochloric acid given below and measuring the volume of hydrogen gas evolved.

Assign the curves to each of the following experiments. **Justify** your answer in each case.

50 mL of 0.1 mol L^{-1} hydrochloric acid at 25°C :

50 mL of 0.2 mol L^{-1} hydrochloric acid at 25°C :

100 mL of 0.1 mol L^{-1} hydrochloric acid at 15°C :

100 mL of 0.2 mol L^{-1} hydrochloric acid at 25°C :

100 mL of 0.1 mol L^{-1} hydrochloric acid in the presence of a catalyst at 25°C

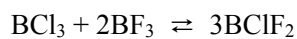
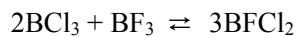
8. [8 marks]

Four unlabelled bottles contain diluted aqueous solutions of NaOH, Na₂CO₃, HCl and H₂SO₄. Propose an analysis scheme that can be used to identify each of the solutions using only the four solutions, Mg powder, and a solution of Ba(NO₃)₂. Your scheme should have no more than four steps. The addition of a particular solution to the various bottles is considered to be one 'test'.

Include **balanced** equations for any reactions occurring.

9. [6 marks]

At 298 K, unequal amounts of $\text{BCl}_3(g)$ and $\text{BF}_3(g)$ are mixed in a container. The gases reacted in the two ways shown below. When equilibrium is finally reached, the four gases were present in these relative molar amounts: BCl_3 (90), BF_3 (470), BClF_2 (200) BFCl_2 (45)



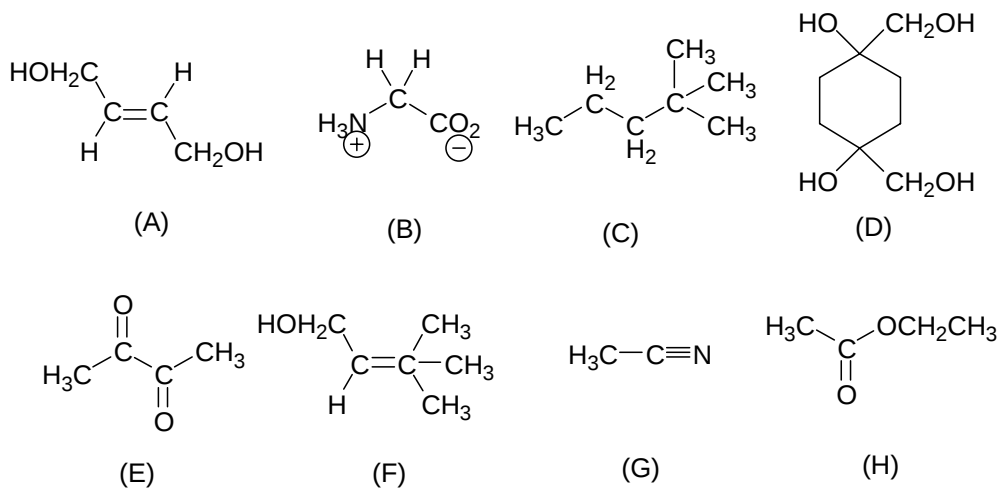
What were the original molar amounts of BF_3 and BCl_3 present based on these results?

10. [2 marks]

Draw a 3-dimensional diagram of N_2H_4 and C_2H_4 .
Explain why they are different

10. [6 marks]

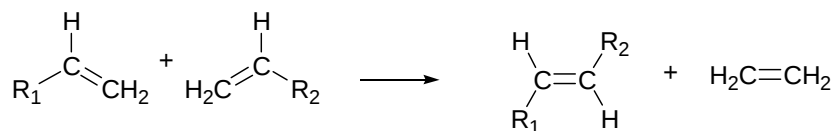
Consider the structures (A) – (H) shown below.



- Which of these structures cannot represent an organic molecule?
- Which three structures have the same empirical formula (i.e. the same ratio of the different elements)?
- Which two structures have the same molecular formula?
- Which compound would be the **least** soluble in a polar solvent such as water?
- Which compound be the **most** soluble in a polar solvent such as water?
- Which compound would be most likely to be found in petroleum?

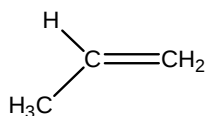
11. [6 marks]

In October 2005, whilst at the University of Canterbury, American chemist Bob Grubbs won the Nobel prize in Chemistry for his work on alkene metathesis. He discovered a catalyst that carries out the general reaction shown below (where R_1 and R_2 can be almost any group).

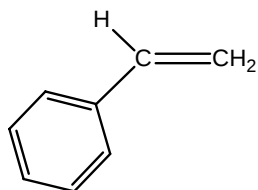


Write structural formulae for the products that would be formed if this reaction was carried out on each of the following organic molecules.

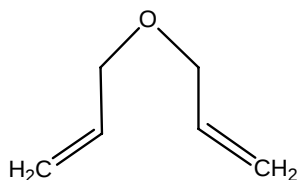
(a)



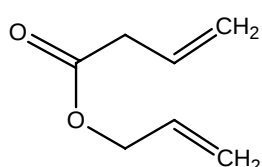
(b)



(c)



(d)



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)			