New Zealand Chemistry Olympiad Trust

Training Group Selection Examination

Wednesday 30 October 2013

TIME ALLOWED: 120 minutes

Answer **ALL** questions on this examination booklet

Calculators may be used

The marks for the **twelve** (12) questions sum to **100**

A periodic table with atomic masses is also provided

STUDENT'S NAME:_____

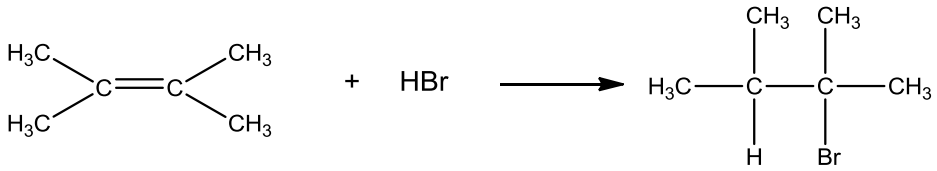
SCHOOL:_____

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

QUESTION ONE (10 marks)

Calculate the minimum volume of HBr solution (48% (w/w) density; 1.490 g mL^{-1}) required for complete reaction with 10.0 g of 2,3-dimethylbut-2-ene.

$M(C_6H_{12})$ = 84.16 g mol^{-1} M(HBr) = 80.92 g mol^{-1}



Useful information:

- Denisty (ρ) provides a link between weight and volume. It usually has the units g mL^{-1}.

$$\rho = \frac{m}{V}$$

- The concentration of liquids is sometimes expressed as weight/weight percent (w/w%) which means the grams of solute/100 grams of solution

QUESTION TWO (10 marks)

In acidic solution, the permanganate ion will oxidise Sn(II) to Sn(IV). The unbalanced redox equation is given below.

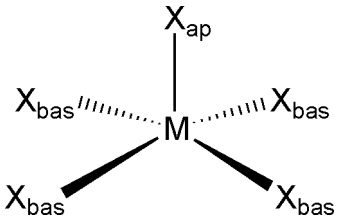
$$Sn^{2+} + MnO_4^- \longrightarrow Sn^{4+} + Mn^{2+}$$

(a) Write the balanced equation for the reaction

(b) A titration is carried out to determine the concentration of a solution of $SnCl_2$. 20.00 mL of an unknown solution of $SnCl_2$ was titrated with a 0.0511 mol L^{-1} solution of potassium permanganate. The mean titre (volume from the burette) was 24.78 mL. Find the concentration of the $SnCl_2$ solution.

QUESTION THREE (5 marks)

The square pyramidal geometry for a compound MX_5 is shown below. There are two types of positions, X_{ap} and X_{bas} (ap = apical; bas = basal).



Sketch the possible isomers for square pyramidal MA_2X_3 in which two groups are different from the other three.

QUESTION FOUR (5 marks)

Hydrogen has two stable isotopes, ^1H, with relative atomic mass 1.008, and deuterium (^2H or D), with relative atomic mass 2.014. Tritium (^3H or T) is a radioactive isotope.

In 1 mol of pure tritium gas, T_2, 2.154×10^{12} decays happen every second. In 1 g of hydrogen gas that contains 0.1 mass percent of tritium, 3.571×10^8 decays happen in a second. What is the relative atomic mass of tritium?

QUESTION FIVE (8 marks)

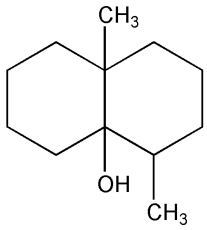
The melting point of bromine is –7 °C. Compare and contrast the melting point of bromine and that of the following compounds by explaining why the melting point for lithium bromide is so much larger while that for iodine chloride is much closer but still bigger than for bromine.

(a) Lithium bromide (550 °C)

(b) Iodine chloride (27 °C)

QUESTION SIX (5 marks)

The odour of geosmine, a compound produced by bacteria in soil with the structure shown to the right, ($C_{12}H_{22}O$), can be detected after rain. Microorganisms produce only one stereoisomer of geosmine.



Note: This is a line diagram in which there is a carbon atom at each end of every line (apart from the OH). The H atoms attached to these carbon atoms are not shown in the diagram.

(a) A chiral centre (an atom with four different groups) gives rise to two stereoisomers. Determine the number of possible stereoisomers in geosmine based on the given structure.

(b) Human olfaction can detect geosmine in the air at a concentration of 3 nanogram L^{-1} (3×10^{-9} g L^{-1}). Calculate the number of geosmine molecules in a mL of air if the odour can be detected in this way.

QUESTION SEVEN (12 marks)

Tetrazene (atom sequence H_2NNNNH_2) decomposes above 0 °C to form hydrazine ($N_2H_4(g)$) and nitrogen gas.

(a) Draw Lewis structures for tetrazene and hydrazine

(b) Determine the bond angles at each N in the structure of tetrazene. Give reasons for your answer.

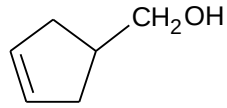
(c) Use the bond enthalpies provided below to determine the enthalpy of the reaction

$$H_2NNNNH_2(g) \rightarrow N_2H_4(g) + N_2(g)$$

Bond	**Bond enthalpy / kJ mol^{-1}**
N-H	391
N-N	158
N=N	470
N≡ N	945

QUESTION EIGHT (10 marks)

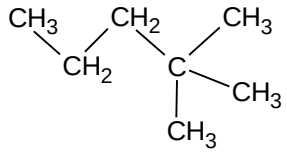
Consider the structures (a) – (g) shown below.

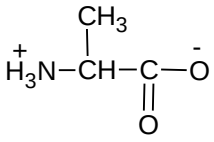
A 

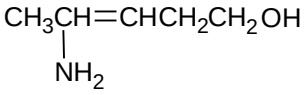
B $CH_3CH_2CH_2CH_2CH_2NH_2$

C $CH_2{=}CHCH_2CH_2CH_2OH$

D $CH_3CH{=}CHCH_2CH{=}CHOH$

E 

F 

G 

(a) Identify the structure that does not represent a real molecular structure. Give a reason for your answer

(b) Identify the structures that are constitutional (structural) isomers. Give a reason for your answer.

(c) Explain why compound C is unable to form stereoisomers (*cis-trans)* while compound D does.

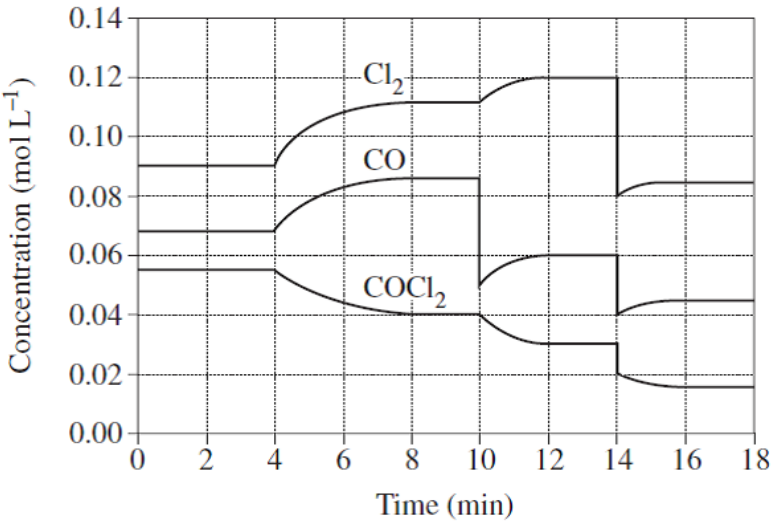
(d) Identify the compound most likely to be found in petrol. _____

(e) Devise a scheme for producing compound B using compound C as the starting material and assuming the availability of common laboratory reagents.

QUESTION NINE (10 marks)

The graph below shows the variation in concentration of reactant and products as a function of time for the following system:

$$COCl_2(g) \rightleftharpoons Cl_2(g) + CO(g) \quad \Delta_r H = +108 \text{ kJ mol}^{-1}$$



Explain which of the changes **I** to **III** is made to the system at times 4, 10 and 14 minutes. Give reasons for your answer.

I Increasing or decreasing pressure (by changing the total volume of the system or by adding an inert gas)

II Addition or removal of heat

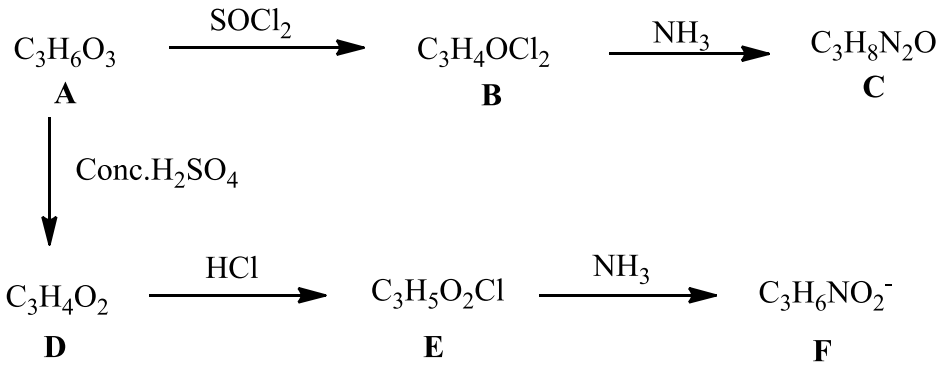
III Addition or removal of one (or more) of the reactants or products.

t = 4 minutes:

t = 10 minutes:

t = 14 minutes:

QUESTION TEN (10 marks)



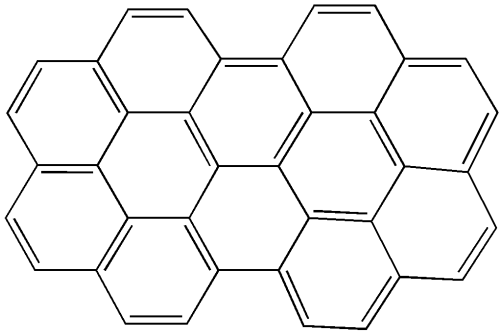
Extra Information

- Compound A has a chiral carbon (i.e. it has one carbon atom that has four different groups attached
- There are two isomers of compound E, a major and a minor product. Compound F is formed from the major product E.
- $SOCl_2$ can be used to substitute a –Cl for the –OH of a carboxylic acid to make an acid chloride. Similarly NH_3 will substitute an $–NH_2$ for the –Cl of an acid chloride
- Compound F is ionic

Determine the structural formulae of Compounds A to F

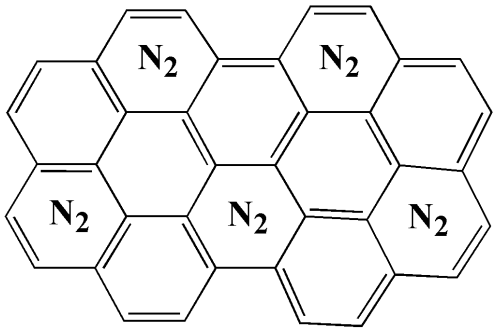
QUESTION ELEVEN (10 marks)

Graphene is made up of a single layer of graphite. A portion of graphene is shown below.



(a) The area of one hexagon is 5.16×10^{-20} m^2.
Estimate the "specific surface" of one face of graphene available for adsorption of other molecules in units of m^2/g.

(b) A single layer of dinitrogen molecules adsorbs on the surface of graphene as shown below.



Calculate the number of grams of nitrogen that can be adsorbed on one gram of graphene. (Assume that adsorption takes place on only one side).

QUESTION TWELVE (5 marks)

Sodium hydrogencarbonate solutions contain the HCO_3^- ion which has the ability to both donate or accept a proton.

(a) Write equations for the two possible reactions of the hydrogencarbonate ion in water

(b) The equilibrium constant for the acid reaction is 4.7×10^{-11} and for the base reaction is 2.2×10^{-8}.
Use the information given above and the equations in (a) to determine whether a solution of sodium hydrogencarbonate is acidic or basic. Justify your answer.

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 **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.	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** 98.9	44 **Ru** 101	45 **Rh** 103	46 **Pd** 106	47 **Ag** 108	48 **Cd** 112	49 **In** 115	50 **Sn** 119	51 **Sb** 122	52 **Te** 128	53 **I** 127	54 **Xe** 131
55 **Cs** 133	56 **Ba** 137	57−71 Lanthanide Series	72 **Hf** 179	73 **Ta** 181	74 **W** 184	75 **Re** 186	76 **Os** 190	77 **Ir** 192	78 **Pt** 195	79 **Au** 197	80 **Hg** 201	81 **Tl** 204	82 **Pb** 207	83 **Bi** 209	84 **Po** 210	85 **At** 210	86 **Rn** 222
87 **Fr** 223	88 **Ra** 226	89−103 Actinide Series	104 **Rf** 261	105 **Db** 262	106 **Sg** 263	107 **Bh** 262	108 **Hs** 265	109 **Mt** 266									

Lanthanide Series	57 **La** 139	58 **Ce** 140	59 **Pr** 141	60 **Nd** 144	61 **Pm** 145	62 **Sm** 150	63 **Eu** 152	64 **Gd** 157	65 **Tb** 159	66 **Dy** 163	67 **Ho** 165	68 **Er** 167	69 **Tm** 169	70 **Yb** 173	71 **Lu** 175
Actinide Series	89 **Ac** 227	90 **Th** 232	91 **Pa** 231	92 **U** 238	93 **Np** 237	94 **Pu** 244	95 **Am** 243	96 **Cm** 247	97 **Bk** 247	98 **Cf** 251	99 **Es** 252	100 **Fm** 257	101 **Md** 258	102 **No** 255	103 **Lr** 262