RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATION (II)

CANDIDATE NAME									
CLASS	6								
CENTRE NUMBER	S					INDEX NUMBER				

H2 CHEMISTRY 9647/03

Paper 3 Free Response

18 September 2015

2 hours

Candidates answer on separate paper.

Additional Materials: Answer Paper
Cover Page
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class, centre number and index number on all the work you hand in.
Write in dark blue or black pen on both sides of paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer any **four** questions.
Begin each question on a fresh sheet of paper.
A Data Booklet is provided. Do not write anything on it.
You are reminded of the need for good English and clear presentation in your answers.

The number of marks is given in brackets [ ] at the end of each question or part question.
At the end of the examination, fasten all your work securely together, with the cover page on top.

This document consists of **12** printed pages.

1 **(a)** **(i)** Sketch the trend of the ionic radii of the ions for the third period of the Periodic Table, from Na to C*l*.

In your sketch, explain the general trend of ionic radii across the period. **[4]**

(ii) Chlorides of aluminium and phosphorus both react readily with water to form acidic solutions. Write equations to illustrate these reactions. **[2]**

(b) Chloric(I) acid, HC*l*O, is a common disinfecting agent used in swimming pools for its strong oxidising ability.

Chloric(I) acid is a weak acid and ionises according to the equation:

$HClO(aq) \rightleftharpoons H^+(aq) + ClO^-(aq)$ $\quad K_a = 3.50 \times 10^{-8}$ mol dm^{-3}

(i) To a swimming pool treated with HC*l*O, $Ca(OH)_2(s)$ was added to maintain a relatively constant pH of 7.6.

Write an equation to show to illustrate the reaction between calcium hydroxide and chloric(I) acid **[1]**

(ii) Given that 56 g of $Ca(OH)_2$ is added, and the swimming pool has a capacity of 2500 m^3, calculate the following:

- $\dfrac{[ClO^-]}{[HClO]}$
- initial [HC*l*O] of the freshly treated swimming pool. **[2]**

(c) **(i)** The level of chloride content in tap water can be quantified by obtaining the mass of lead required to precipitate lead(II) chloride.

At 298K, the solubility of lead(II) chloride is 2.45×10^{-2} mol dm^{-3}. Calculate the solubility product of lead(II) chloride. **[1]**

(ii) Given that the acceptable limit of chloride ions in tap water is 250 ppm, calculate the minimum mass of lead required for precipitation to occur in a 50 cm^3 sample of tap water.

You may ignore the low concentration of lead(II) ions originally found in tap water. (1 ppm = 1 mg per litre) **[2]**

(d) A compound **M** has a molecular formula of $C_8H_{10}O_2$, and gives purple colour with aqueous iron(III) chloride. When hot acidic potassium dichromate(VI) is added to **M**, the orange solution turns green and compound **N** is formed. 1 mol of **N** reacts with 1 mol of phosphorus chloride to give compound **P**, which on further warming with sodium, produces a neutral compound **Q** that has a formula of $C_8H_6O_2$.

Suggest the structures of **M**, **N**, **P** and **Q**, and explain your reasoning. **[8]**

[Total: 20]

2. Nitrogen is a colourless and odourless gas that makes up of about 78% of the Earth's atmosphere. Many useful industrial products such as ammonia, nitric acid and organic nitrates incorporate nitrogen. However, conversion of free nitrogen to these useful products has proved to be an industrial challenge.

(a) The production of many nitrogen compounds usually starts from the conversion of nitrogen to ammonia via the Haber process. Nitrogen and hydrogen were placed in a 2.20 dm^3 vessel containing iron powder. Temperature and pressure were maintained at 450 °C and 20 atm respectively.

Calculate the total number of moles of gas. You may assume that all gases behave ideally at the given condition. **[1]**

(b) A 1 mol sample of $NH_3(g)$ was extracted and placed in a 10 dm^3 container. Pressure measurements were taken and compared against a sample of 1 mol of an ideal gas in an identical 10 dm^3 container and the following data was obtained at two separate temperature:

	NH_3 (450°C)	NH_3 (25°C)	Ideal gas (450°C)	Ideal gas (25°C)
Pressure/atm	5.91	1.58	5.95	2.45

Suggest why pressure exerted by both gases are similar at 450 °C but significantly different at 25 °C. **[2]**

(c) Ammonium nitrate is a very soluble salt and is primarily used as a chemical fertiliser. Ammonia can be converted to ammonium nitrate in the following processes:

Process 1: Gaseous ammonia is oxidised in air at high temperature to form nitrogen(IV) oxide and steam.

Process 2: This gaseous nitrogen(IV) oxide is then dissolved in water to produce nitric acid as well as nitrogen(II) oxide as the only by-product.

Process 3: Nitric acid is then mixed with aqueous ammonia to form ammonium nitrate.

The following data may be required for the subsequent questions:

Compound	ΔH_f/kJ mol^{-1}
$NH_3(g)$	–45
$NH_3(aq)$	–80.8
$HNO_3(aq)$	–207
$H_2O(l)$	–285

(i) Write balanced equations including state symbols for process 1 and 2. **[2]**

(ii) Given that process 2 mentioned in **(c)** is exothermic, suggest how temperature for this reaction should be controlled to maximize the yield of nitric acid. **[2]**

(iii) Given that the enthalpy change of reaction between aqueous ammonia and nitric acid is –52.2 kJmol^{-1}, calculate a value for the enthalpy change of formation of aqueous ammonium nitrate by means of an energy cycle. **[2]**

(d) Nitric acid is also used to manufacture nitrobenzene. Concentrated sulfuric acid is added as a catalyst. Describe the mechanism of this reaction. **[3]**

(e) Nitrobenzene that is produced can be converted to phenylamine, which is considered as a weak base.

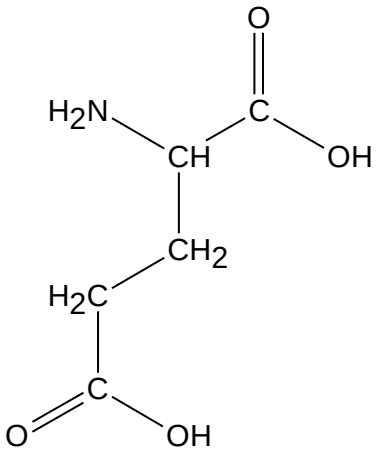
State and comment on the relative base strength of phenylamine compared to ammonia. **[2]**

(f) The structure of protein can be classified into the primary, secondary, tertiary and quaternary structure.

(i) Explain what is meant by a secondary structure of a protein **[1]**

(ii) With an aid of a diagram, describe the bonding in a β-pleated sheet. **[3]**

(iii) Proteins are polymers made up of monomers of amino acids. One such amino acid is glutamic acid:



The pK_a values associated with this molecule is 2.10, 4.07 and 9.47.

Propose the structure of glutamic acid at pH 7 and pH 3. **[2]**

[Total: 20]

3. (a) Cyanohydrins can be made by reacting ketones with an acidified solution of sodium cyanide.

$$(CH_3)_2C{=}O + H^+ + CN^- \rightarrow (CH_3)_2C(OH)CN$$

Kinetic studies were performed on the reaction by varying the concentration of reagents, and the following results were obtained.

Expt No.	$[(CH_3)_2C{=}O]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	$[CN^-]$ / mol dm^{-3}	Time / min
1	0.020	0.050	0.060	1.00
2	0.020	0.050	0.050	1.20
3	0.020	0.060	0.050	1.20
4	0.025	0.050	0.050	0.96

(i) Define the term *order of reaction*. **[1]**

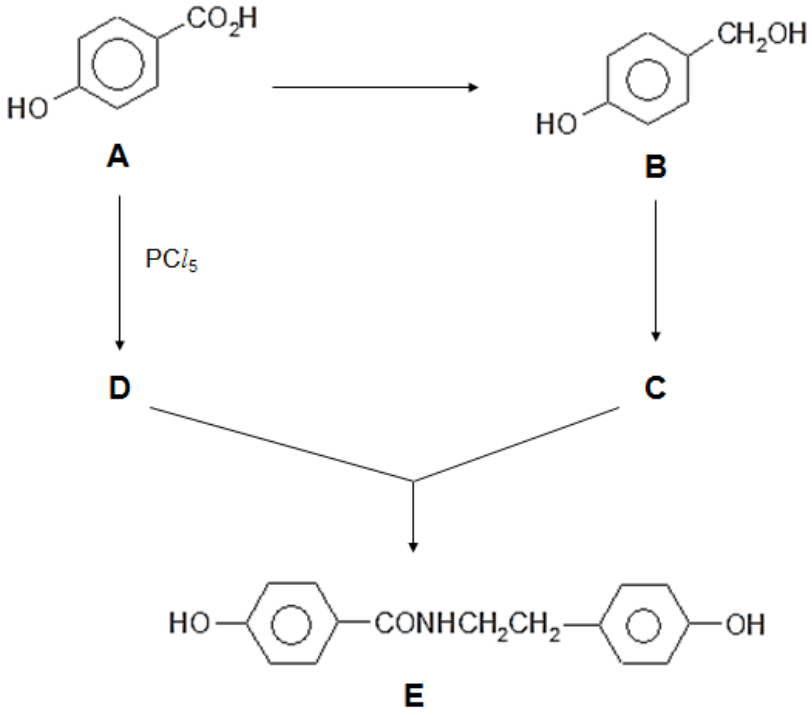
(ii) Determine the order of the reaction with respect to propanone, hydrogen ion and cyanide ion. Show your working in each case. **[3]**

(iii) Hence, write down the rate equation for the reaction. **[1]**

(iv) Describe the mechanism if the reaction is found to proceed via two steps. **[2]**

(v) With the aid of a Maxwell-Boltzmann distribution curve, explain how an increase in temperature will impact the rate of reaction. **[3]**

(b) Study the following reaction scheme.



(i) Draw the displayed formula of compound **D**. **[1]**

(ii) Propose a synthetic route of not more than 3 steps to convert compound **B** to **C**. Include all reagents and conditions, as well as the structures of any intermediates formed in your answer. **[3]**

(c) **(i)** Given that the pK_a of benzoic acid is 4.19, calculate the pH of 0.200 mol dm^{-3} benzoic acid. **[3]**

(ii) 20 cm^3 of 0.200 mol dm^{-3} benzoic acid was titrated against 0.200 mol dm^{-3} potassium hydroxide.

Write an equation to show that the pH at equivalence point will be more than 7. **[1]**

(iii) Hence, sketch the pH curve of this titration using information from **(c)(i)** and **(c)(ii)**. **[2]**

[Total: 20]

4 **(a)** When the nitrates of Group I metals (Li, Na, K, Rb, Cs) are heated they decompose in one of the following ways.

Option A: $2\boldsymbol{M}NO_3(s) \rightarrow 2\boldsymbol{M}NO_2(s) + O_2(g)$

Option B: $4\boldsymbol{M}NO_3(s) \rightarrow 2\boldsymbol{M}_2O(s) + 4NO_2(g) + O_2(g)$

where ***M*** is a Group I metal

A 3.00 g of white solid which contains 95% by mass of $LiNO_3$ undergoes thermal decomposition to release 1240 cm^3 of gas under room temperature and pressure.

By means of calculation, determine the correct option.

[3]

(b) Nitrates of Group II also undergoes thermal decomposition just like nitrates of Group I. Explain the differences in the thermal decomposition temperatures for $LiNO_3$ and $Be(NO_3)_2$ as shown in the table below.

Compound	Thermal decomposition temperature / ^oC
$LiNO_3$	474
$Be(NO_3)_2$	125

[3]

(c) In contrast to lithium nitrate, chromium(III) nitrate dissolves in water to give a purple solution. Account for its colour.

[3]

(d) When aqueous ammonium dichromate(VI), $(NH_4)_2Cr_2O_7$, is added gradually to molten ammonium thiocyanate, NH_4SCN, an ammonium salt known as Reinecke's salt, **J**, is formed. **J** has the formula $NH_4[Cr(SCN)_{\boldsymbol{x}}(NH_3)_{\boldsymbol{y}}]$, and analysis produced the following composition by mass:

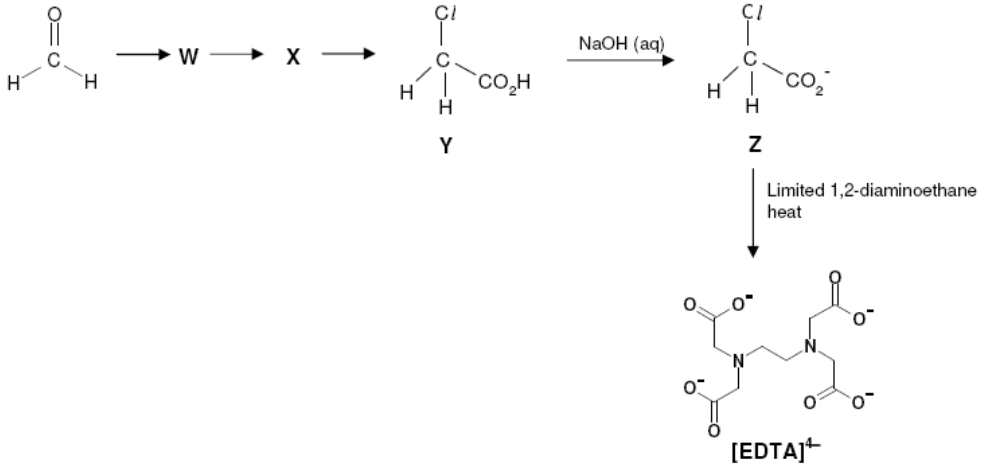
Cr, 15.5 %; S, 38.1 %; N, 29.2 %

(i) Determine the values of ***x*** and ***y*** in the in the salt **J**. **[3]**

(ii) State the oxidation number of chromium in salt **J**. **[1]**

(e) Ethylenediamine tetraacetate, $[EDTA]^{4-}$, is a chelating agent that is widely used to remove transition metal ions such as those of chromium from aqueous solutions.

A possible reaction scheme used to synthesize $[EDTA]^{4-}$ from methanal is given below.



(i) Explain what is meant by a ligand. **[1]**

(ii) Name the type of reaction that converts **Z** to $EDTA^{4-}$. **[1]**

(iii) Give the reagents and conditions in each step for the conversion from methanal to compound **Y**. Draw the structures of intermediates **W** and **X**. **[5]**

[Total: 20]

5. This question is about acids and their reactions.

(a) Nucleophilic reagents, such as gases of hydrogen chloride and hydrogen bromide, can be prepared in situ by reacting solid potassium halides with concentrated sulfuric acid.

(i) Describe and explain, with the aid of equations, what you would observe when concentrated sulfuric acid is added to separate samples of solids potassium chloride and potassium bromide. **[4]**

(ii) Explain, with the aid of an equation, why hydrogen iodide cannot be prepared using concentrated sulfuric acid unlike other hydrogen halides. **[2]**

(b) Gold exists commonly in +3 oxidation state. However in nature, gold exists mainly as a metal alloyed to other metals such as silver (as electrum), or sometimes with mercury (as an amalgam).

Native gold can be separated from other elements by dissolving it in aqua regia – a mixture of concentrated nitric acid and hydrochloric acid in a ratio of 1:3.

Answer the questions that follow, using the Data Booklet and the following standard reduction potentials given below.

$Au^{3+}(aq) + 3e \rightleftharpoons Au(s)$ $\quad E^{\ominus}_{red} = +1.50\ V$

$AuCl_4^-(aq) + 3e \rightleftharpoons Au(s) + 4\ Cl^-(aq)$ $\quad E^{\ominus}_{red} = +1.00\ V$

$NO_3^-(aq) + 4H^+(aq) + 3e \rightleftharpoons NO(g) + 2H_2O(l)$ $\quad E^{\ominus}_{red} = +0.96\ V$

(i) Explain why gold does not tarnish in air. **[1]**

(ii) Write a balanced equation for the reaction of gold, hydrochloric acid and nitric acid to produce tetrachloroaurate(IV), $AuCl_4^-$, and nitrogen monoxide gas. **[1]**

(iii) By means of calculation, show that the reaction in **b(ii)** is not expected to be spontaneous. **[1]**

(iv) Considering your answer for **b(iii)**, explain why gold can be dissolved in aqua regia. **[3]**

(v) Suggest a suitable reagent and briefly describe how one can safely recover pure gold solid from a mixture containing $AuCl_4^-$ and excess aqua regia. **[3]**

(c) Chlorine forms acidic compounds with distinctly different acid strength.

(i) State and explain the relative acidity of methanol, methanoic acid and phenol. **[3]**

(ii) With reference to the structure of ClO_3^-, predict with justification the acidity of $HClO_3$ relative to the acids listed in **(c)(i)**. **[2]**

[Total: 20]