NCUK

THE NCUK INTERNATIONAL FOUNDATION YEAR

IFYCH002 Chemistry
Examination
2016-17

Examination Session
Semester Two

Time Allowed
2 Hours 40 minutes
(including 10 minutes reading time)

INSTRUCTIONS TO STUDENTS

SECTION A	Answer ALL questions. This section carries 40% of the exam marks.
SECTION B	Answer 3 questions ONLY. This section carries 60% of the exam marks.

The marks for each question are indicated in square brackets [ ].

- Answers must not be written during the first 10 minutes.
- A data sheet is included in the front of the examination booklet.
- Graph paper will be provided.
- An approved calculator may be used in the examination.
- Show **ALL** workings in your answer booklet.
- Examination materials must not be removed from the examination room.

DO NOT OPEN THIS QUESTION PAPER UNTIL INSTRUCTED BY THE INVIGILATOR

The Periodic Table of the Elements

- The atomic numbers and approximate relative atomic masses shown in the table are for use in the examination unless stated otherwise in an individual question.

Key

relative atomic mass ——— 6.9 **Li** Lithium
atomic number ——— 3

I	II												III	IV	V	VI	VII	0
1.0 **H** Hydrogen 1																		4.0 **He** Helium 2
6.9 **Li** Lithium 3	9.0 **Be** Beryllium 4												10.8 **B** Boron 5	12.0 **C** Carbon 6	14.0 **N** Nitrogen 7	16.0 **O** Oxygen 8	19.0 **F** Fluorine 9	20.2 **Ne** Neon 10
23.0 **Na** Sodium 11	24.3 **Mg** Magnesium 12												27.0 **Al** Aluminium 13	28.1 **Si** Silicon 14	31.0 **P** Phosphorus 15	32.1 **S** Sulphur 16	35.5 **Cl** Chlorine 17	39.9 **Ar** Argon 18
39.1 **K** Potassium 19	40.1 **Ca** Calcium 20	45.0 **Sc** Scandium 21	47.9 **Ti** Titanium 22	50.9 **V** Vanadium 23	52.0 **Cr** Chromium 24	54.9 **Mn** Manganese 25	55.8 **Fe** Iron 26	58.9 **Co** Cobalt 27	58.7 **Ni** Nickel 28	63.5 **Cu** Copper 29	65.4 **Zn** Zinc 30		69.7 **Ga** Gallium 31	72.6 **Ge** Germanium 32	74.9 **As** Arsenic 33	79.0 **Se** Selenium 34	79.9 **Br** Bromine 35	83.8 **Kr** Krypton 36
85.5 **Rb** Rubidium 37	87.6 **Sr** Strontium 38	88.9 **Y** Yttrium 39	91.2 **Zr** Zirconium 40	92.9 **Nb** Niobium 41	95.9 **Mo** Molybdenum 42	98.9 **Tc** Technetium 43	101.1 **Ru** Ruthenium 44	102.9 **Rh** Rhodium 45	106.4 **Pd** Palladium 46	107.9 **Ag** Silver 47	112.4 **Cd** Cadmium 48		114.8 **In** Indium 49	118.7 **Sn** Tin 50	121.8 **Sb** Antimony 51	127.6 **Te** Tellurium 52	126.9 **I** Iodine 53	131.3 **Xe** Xenon 54
132.9 **Cs** Caesium 55	137.3 **Ba** Barium 56	138.9 **La** Lanthanum 57 *	178.5 **Hf** Hafnium 72	180.9 **Ta** Tantalum 73	183.9 **W** Tungsten 74	186.2 **Re** Rhenium 75	190.2 **Os** Osmium 76	192.2 **Ir** Iridium 77	195.1 **Pt** Platinum 78	197.0 **Au** Gold 79	200.6 **Hg** Mercury 80		204.4 **Tl** Thallium 81	207.2 **Pb** Lead 82	209.0 **Bi** Bismuth 83	210.0 **Po** Polonium 84	210.0 **At** Astatine 85	222.0 **Rn** Radon 86
223.0 **Fr** Francium 87	226.0 **Ra** Radium 88	227 **Ac** Actinium 89 †																

* 58 – 71 Lanthanides

140.1 **Ce** Cerium 58	140.9 **Pr** Praseodymium 59	144.2 **Nd** Neodymium 60	144.9 **Pm** Promethium 61	150.4 **Sm** Samarium 62	152.0 **Eu** Europium 63	157.3 **Gd** Gadolinium 64	158.9 **Tb** Terbium 65	162.5 **Dy** Dysprosium 66	164.9 **Ho** Holmium 67	167.3 **Er** Erbium 68	168.9 **Tm** Thulium 69	173.0 **Yb** Ytterbium 70	175.0 **Lu** Lutetium 71

† 90 – 103 Actinides

232.0 **Th** Thorium 90	231.0 **Pa** Protactinium 91	238.0 **U** Uranium 92	237.0 **Np** Neptunium 93	239.1 **Pu** Plutonium 94	243.1 **Am** Americium 95	247.1 **Cm** Curium 96	247.1 **Bk** Berkelium 97	252.1 **Cf** Californium 98	252.0 **Es** Einsteinium 99	(257) **Fm** Fermium 100	(258) **Md** Mendelevium 101	(259) **No** Nobelium 102	(260) **Lr** Lawrencium 103

Data Sheet

Infrared spectroscopy: Characteristic absorptions for functional groups	
Bond	**Wave number / cm^{-1}**
C-Br	500 - 600
C-Cl	650 - 800
C-O	1000 - 1300
C=C	1620 - 1670
C=O	1650 - 1750
C=N	2100 - 2250
C-H	2800 - 3100
O-H	2500 - 3550
N-H	3300 – 3500

Section A
Answer ALL questions. This section carries 40 marks.

Question A1

What is the electronic configuration of the element chromium? **[1]**

a) $1s^2 2s^2 2p^6 3s^2 3p^5 4s^2 3d^5$

b) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^6$

c) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$

d) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^4$

Question A2

Which of the following has the same number of particles as 3.00g of ^{12}C? **[1]**

a) 3.00g of Be

b) 4.50g of H_2O

c) 6.00g of Cr

d) 24.3g of Mg

Question A3

What type of bonding exists between sulphur and oxygen in the compound **[1]** sulphur dioxide (SO_2)?

a) Covalent bonding

b) Coordinate bonding

c) Metallic bonding

d) Ionic bonding

Question A4

What is the shape of the ion NH_4^+?   **[1]**

a)   Pyramidal

b)   Square Planar

c)   Trigonal planar

d)   Tetrahedral

Question A5

Which of the following elements has the lowest first ionisation energy?   **[1]**

a)   Magnesium

b)   Aluminium

c)   Phosphorus

d)   Sulphur

Question A6

How does a Maxwell-Boltzman distribution of energies diagram change if the   **[1]**
temperature is decreased?

a)   Stays in the same place and area under curve stays the same.

b)   Stays in the same place and area under curve increases.

c)   Moves to the left and area under curve increases.

d)   Moves to the left and area under curve stays the same.

Question A7

What is the correct reagent and observation when testing for the sulphate ion ? **[1]**

a)   Silver nitrate, White precipitate

b)   Silver nitrate, Cream precipitate

c)   Barium chloride, White precipitate

d)   Barium chloride, Cream precipitate

Question A8

What is the name of the mechanism of the reaction in which ethanol reacts with ethanoyl chloride to form ethylethanoate and hydrogen chloride? **[1]**

a)   Nucleophilic addition

b)   Nucleophilic substitution

c)   Elimination

d)   Nucleophilic addition-elimination

Question A9

How many additional structural isomers does the compound 2-methylpropan-2-ol have? **[1]**

a)   1

b)   2

c)   3

d)   4

Question A10

What is the correct structural formula for the compound methyl 2-methylpropenoate? **[1]**

a) $CH_2CHCH_2COOCH_3$

b) $CH_2CHCOOCH_2CH_3$

c) $CH_2C(CH_3)COOCH_3$

d) $CH_3CH(CH_3)COOCH_3$

Question A11

This question is organic chemistry.

a) Name a reagent and the positive observation when testing for:

    i.   a primary or secondary alcohol   **[2]**

    ii.   an aldehyde   **[2]**

    iii. a carboxylic acid   **[2]**

    iv. an acyl chloride   **[2]**

b) Draw the structural formulae of the oxidation product of butan-2-ol. Give the name of the product.   **[2]**

Question A12

2.82g of X_2CO_3 was made up to $250cm^3$ with distilled water in a volumetric flask. A $25.0cm^3$ portion of this solution required $27.2cm^3$ of $0.150moldm^{-3}$ HCl solution to be completely neutralised.

a) Calculate the number of moles in $27.2cm^3$ of $0.150moldm^{-3}$ HCl solution.   **[1]**

b) Hence deduce the number of moles of X_2CO_3 in the $25.0cm^3$ portion. Use your answer to calculate the number of moles of X_2CO_3 in the $250cm^3$ volumetric flask.   **[3]**

c) Use the number of moles you have calculated in (b) and the mass of X_2CO_3 to calculate the Mr of X_2CO_3. Give your answer to 1 decimal place.   **[3]**

d) Use your answer to (c) and the periodic table on the data sheet to find the Ar of X.   **[2]**

e) Hence deduce the identity of X using the periodic table on the data sheet   **[1]**

Question A13

This question is about redox chemistry.

a) i.   State, in terms of electrons, what happens to a oxidising agent in a redox reaction.   **[1]**

    ii. State the oxidation number of sulphur in each of the following compounds:

        I H_2SO_4 **[1]**

        II H_2S **[1]**

        III SO_3 **[1]**

b) A fuel cell supplied with hydrogen gas and oxygen gas can be used to generate a current via a redox process in which the only product is water (formed by the combination of hydrogen ions and hydroxide ions).

    i. Write a half equation to show how oxygen gas, O_2, is reduced in aqueous solution to form hydroxide ions. **[1]**

    ii. Write a half equation to show how hydrogen gas is oxidised to form hydrogen ions. **[1]**

    iii. Combine the two half equations to give the overall redox equation for the fuel cell. **[1]**

c) Use the following reaction to describe what is meant by 'disproportionation': **[3]**

$$Cl_2 + H_2O \longrightarrow HCl + HClO$$
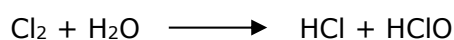
Section B begins on the following page.

Section B
Answer <u>3</u> questions. This section carries 60 marks.

Question B1

This question is about the synthesis of some organic compounds.

a) 1-Methyl-4-nitrobenzene can be produced from methylbenzene in an electrophilic substitution reaction.

   i.   Write equations to show the preparation of the electrophile which reacts with methylbenzene in this reaction. Include the name of the catalyst used. **[2]**

   ii. Write a mechanism for this reaction. **[3]**

   iii. Write an equation to show how the catalyst is regenerated. **[1]**

b) When propene reacts with hydrogen chloride a major product and a minor product are formed.

   i.   Write the name of the mechanism for this reaction. **[1]**

   ii. Write a mechanism for the reaction which forms the major product. **[4]**

   iii. Name the major product and explain why it is the major product of the reaction. **[3]**

c) When aqueous sodium borohydride ($NaBH_4$) reacts with pentan-2-one, a product containing a chiral carbon is formed.

   i.   Explain what is meant by the term **chiral carbon**. **[1]**

   ii. What is the name of the mechanism for this reaction? **[1]**

   iii. Write a mechanism for this reaction. **[4]**

Question B2

a) Explain how mass spectrometry can be used to determine the relative atomic mass of elements. Include a brief description of how the sample is ionised, separated and detected.   **[6]**

b) Analytical techniques such as IR and NMR can be used to identify organic compounds such as 2-aminoethanoic acid and 3-chloropropanoic acid.

    i.   Draw the skeletal structure of 2-aminoethanoic acid.   **[1]**

    ii.   List the absorptions you would expect to see in the IR spectrum of 2-aminoethanoic acid using the data sheet.   **[4]**

    iii.   How many peaks would be seen in the ^{1}H NMR of 3-chloropropanoic acid? What would the relative intensities of the peaks be, and how would they be split?   **[3]**

c) 2-Bromo-1,1,1-trifluoroethane can be formed from bromine and 1,1,1-trifluoroethane in a free radical substitution reaction.

    i.   State the conditions required for the reaction to occur.   **[1]**

    ii.   The initiation stage involves a covalent bond breaking homolytically. Explain the meaning of the term **homolytically**. Illustrate your explanation with an equation.   **[2]**

    iii.   Write equations for the propagation stages of the reaction.   **[2]**

    iv.   Write an equation to show the termination stage which leads to the formation of 1,1,1,4,4,4-hexafluorobutane.   **[1]**

Question B3

This question is about the Haber process:

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \qquad \Delta H = -93.0 kJmol^{-1}$$
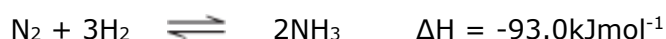
a) Calculate the bond energy of the N-H bond using the ΔH value given for the reaction and the bond energy data in the table below: **[3]**

	kJmol^{-1}
N≡N bond energy	945
H-H bond energy	436
N-H bond energy	?

b) i.   Use le Chatelier's principle to describe how an increase in pressure would affect the equilibrium yield of ammonia in the Haber process.   **[3]**

    ii.   Use le Chatelier's principle to describe how an increase in temperature would affect the equilibrium yield of ammonia in the Haber process.   **[3]**

    iii.   Write an expression for the equilibrium constant, K_p, for this reaction.   **[1]**

iv. 1.50 moles of nitrogen was added to 2.50 moles of hydrogen at 700K and the reaction was left to reach equilibrium in the presence of an iron catalyst. The equilibrium mixture was found to contain 1.78 moles of hydrogen, and had a total pressure of 200 atmospheres.

    I   Calculate the number of moles of nitrogen and ammonia at equilibrium.   **[2]**

    II   Calculate the partial pressure of the nitrogen, hydrogen and ammonia at equilibrium.   **[3]**

    III   Calculate K_p. Give your answer to 3 significant figures. Include the units in your answer.   **[4]**

v. What effect does the addition of the iron catalyst have upon the rate of attainment of the equilibrium?   **[1]**

Question B4

This is a question about transition metals.

a) In which block of the periodic table are the transition metals found?   **[1]**

b) State four properties of transition metals.   **[4]**

c) i. A complex ion consists of 30.9% copper(II), with the remainder being chlorine in the form of chloride ions. Calculate the empirical formula of the complex ion. Write the structure of the complex ion.   **[4]**

    ii. Draw the three dimensional structure of the complex ion in (i) above and name its shape.   **[2]**

    iii. The chloride ion in the complex ion above is an example of a ligand. Explain what is meant by a **ligand**.   **[3]**

    iv. Copper ions can be removed from aqueous solution using a hexadentate ligand, $EDTA^{4-}$:

$$[Cu(H_2O)_6]^{2+} + EDTA^{4-} \longrightarrow Cu(EDTA)^{2-} + 6H_2O$$

    I   Explain what is meant by **hexadentate** ?   **[1]**

    II   Explain why the reaction above leads to a positive entropy change.   **[2]**

d) A sample of copper found on a meteorite had the following isotopic abundances: ^{63}Cu 28.7%, ^{65}Cu 69.8%, ^{67}Cu 1.5%. Calculate the relative atomic mass of this sample of copper. Give your answer to 1 decimal place.   **[3]**

Question B5

a) i.   Write an expression for the ionic product of water, Kw.   **[1]**

ii.   Use the expression to calculate the pH of pure water at 333K, if the value of Kw at this temperature is 9.31×10^{-14} mol^2dm^{-6}. Give your answer to two decimal places.   **[4]**

iii.   Write an equation to show the dissociation of pure water. Use the equation and your answer to the question above to explain whether the dissociation of water is an exothermic or an endothermic process.   **[3]**

iv.   Calculate the pH of a 0.0255 $moldm^{-3}$ solution of magnesium hydroxide at 333K.   **[3]**

b)   Propanoic acid is a weak acid with a pKa of 4.87 at 298K. Calculate the pH of a 0.176 $moldm^{-3}$ solution of propanoic acid at 298K.   **[4]**

c)   Define the following terms:

i.   Equivalence point.   **[1]**

ii.   End point.   **[1]**

iii.   Indicator.   **[1]**

d)   What are the properties of a good indicator?   **[2]**

This is the end of the examination.