Surname		Other Names	
Centre Number						Candidate Number				
Candidate Signature										

General Certificate of Education
June 2004
Advanced Level Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

CHEMISTRY **CHM6/W**
Unit 6a Synoptic Assessment

Tuesday 29 June 2004 Morning Session

In addition to this paper you will require:
- an objective test answer sheet;
- a black ball-point pen;
- a calculator.

Time allowed: 1 hour

Instructions
- Use a black ball-point pen. Do **not** use pencil.
- Fill in the boxes at the top of this page.
- Answer **all** 40 questions.
- For each item there are four responses. When you have selected the response which you think is the best answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book, **not** on your answer sheet.
- Make sure that you hand in **both** your answer sheet **and** this question paper at the end of this examination.
- The Periodic Table/Data Sheet is provided on pages 3 and 4. Detach this perforated sheet at the start of the examination.

Information
- The maximum mark for this paper is 40.
- Each correct answer will score one mark. No deductions will be made for wrong answers.
- This paper carries 10 per cent of the total marks for Advanced Level.
- The following data may be required.
  Gas constant $R = 8.31\,\text{J}\,\text{K}^{-1}\,\text{mol}^{-1}$

Advice
- Do not spend too long on any question. If you have time at the end, go back and answer any question you missed out.

NO QUESTIONS APPEAR ON THIS PAGE

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.

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 †															

Key

relative atomic mass — 6.9 **Li** Lithium

atomic number — 3

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
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) **Es** Einsteinium 99	(257) **Fm** Fermium 100	(258) **Md** Mendelevium 101	(259) **No** Nobelium 102	(260) **Lr** Lawrencium 103

* **58 – 71** Lanthanides

† **90 – 103** Actinides

Table 1
Proton n.m.r chemical shift data

Type of proton	**δ/ppm**
RCH_3	0.7–1.2
R_2CH_2	1.2–1.4
R_3CH	1.4–1.6
$RCOCH_3$	2.1–2.6
$ROCH_3$	3.1–3.9
$RCOOCH_3$	3.7–4.1
ROH	0.5–5.0

Table 2
Infra-red absorption data

Bond	**Wavenumber/cm^{-1}**
C—H	2850–3300
C—C	750–1100
C═C	1620–1680
C═O	1680–1750
C—O	1000–1300
O—H (alcohols)	3230–3550
O—H (acids)	2500–3000

Multiple choice questions

Each of Questions **1** to **20** consists of a question or an incomplete statement followed by four suggested answers or completions. You are to select the most appropriate answer in each case.

Questions 1 and 2

Use the information below to answer Questions **1** and **2**.

$$C(s) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H^{\ominus} = -393.5\,kJ\,mol^{-1}$$

$$H_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow H_2O(l) \qquad \Delta H^{\ominus} = -285.8\,kJ\,mol^{-1}$$

$$3C(s) + 4H_2(g) \longrightarrow C_3H_8(g) \qquad \Delta H^{\ominus} = -104.0\,kJ\,mol^{-1}$$

$$4C(s) + 5H_2(g) \longrightarrow C_4H_{10}(g) \qquad \Delta H^{\ominus} = -125.2\,kJ\,mol^{-1}$$

1 The value in $kJ\,mol^{-1}$ of the enthalpy of thermal dissociation when butane forms propane, hydrogen and carbon is

A −26.3

B −17.5

C +17.5

D +21.2

2 The value in $kJ\,mol^{-1}$ for the enthalpy of combustion of propane is

A −211.7

B −419.7

C −2220

D −2878

3 The equation for the combustion of butane in oxygen is

$$C_4H_{10} + 6\tfrac{1}{2}O_2 \longrightarrow 4CO_2 + 5H_2O$$

The mole fraction of butane in a mixture of butane and oxygen with the minimum amount of oxygen required for complete combustion is

A 0.133

B 0.153

C 0.167

D 0.200

Turn over ▶

Questions 4 to 6

Use the information below to answer Questions **4** to **6**.

Ethanoic acid reacts with ethanol in a reversible reaction represented by the equation below. In an experiment 3.0 mol of ethanoic acid were mixed with 1.0 mol of ethanol and when the reaction had reached equilibrium 0.9 mol of water had been formed.

$$CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$$

4 The equilibrium constant for the reaction under these conditions is

A 0.20

B 0.23

C 3.9

D 4.3

5 The percentage of ethanoic acid converted into the ester $CH_3COOC_2H_5$ in this reaction is

A 22.5%

B 30%

C 43%

D 90%

6 Which one of the following statements is **not** correct concerning the ester $CH_3COOC_2H_5$?

A It absorbs infra-red radiation strongly at a wavenumber of about 1700 cm^{-1}.

B It has a major peak in its mass spectrum with $m/z = 43$.

C It has three peaks in its proton n.m.r. spectrum.

D Two of the peaks in its proton n.m.r. spectrum are split into triplets.

7 Which one of the following will produce a saturated solution with the highest pH?

A barium hydroxide

B beryllium hydroxide

C calcium hydroxide

D strontium hydroxide

8 A particular sample of iron ore contains 85% by mass of Fe_2O_3 (M_r = 159.6) and no other iron compound. The maximum mass of iron that could be extracted from 1.0 tonne of this ore is

A 0.59 tonne

B 0.66 tonne

C 0.75 tonne

D 0.85 tonne

9 In which one of the following reactions does hydrogen **not** act as a reducing agent?

A $H_2 + Ca \longrightarrow CaH_2$

B $2H_2 + O_2 \longrightarrow 2H_2O$

C $H_2 + CH_2{=}CH_2 \longrightarrow CH_3CH_3$

D $2H_2 + CH_3COCH_3 \longrightarrow CH_3CH_2CH_3 + H_2O$

TURN OVER FOR THE NEXT QUESTION

10 In which one of the following reactions is the role of the reagent stated correctly?

	Reaction	**Role of reagent**
A	$TiO_2 + 2C + 2Cl_2 \longrightarrow TiCl_4 + 2CO$	TiO_2 is an oxidising agent
B	$HNO_3 + H_2SO_4 \longrightarrow H_2NO_3^+ + HSO_4^-$	HNO_3 is a Brønsted–Lowry acid
C	$CH_3COCl + AlCl_3 \longrightarrow CH_3CO^+ + AlCl_4^-$	$AlCl_3$ is a Lewis base
D	$2CO + 2NO \longrightarrow 2CO_2 + N_2$	CO is a reducing agent

11 Which one of the following could act either as an oxidising agent or as a reducing agent?

A MnO_4^-

B VO^{2+}

C CrO_4^{2-}

D VO_3^-

12
$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l) \qquad E^\ominus = +1.33\ V$$
$$Br_2(aq) + 2e^- \longrightarrow 2Br^-(aq) \qquad E^\ominus = +1.09\ V$$
$$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq) \qquad E^\ominus = +0.77\ V$$
$$VO^{2+}(aq) + 2H^+(aq) + e^- \longrightarrow V^{3+}(aq) + H_2O(l) \qquad E^\ominus = +0.34\ V$$
$$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \longrightarrow H_2SO_3(aq) + H_2O(l) \qquad E^\ominus = +0.17\ V$$

Based on the above data, which one of the following could reduce 0.012 mol of bromine to bromide ions?

A $40\,cm^3$ of a $0.10\,mol\,dm^{-3}$ solution of $Cr_2O_7^{2-}(aq)$

B $80\,cm^3$ of a $0.30\,mol\,dm^{-3}$ solution of $Fe^{3+}(aq)$

C $50\,cm^3$ of a $0.24\,mol\,dm^{-3}$ solution of $V^{3+}(aq)$

D $50\,cm^3$ of a $0.24\,mol\,dm^{-3}$ solution of $H_2SO_3(aq)$

13 An equation for the incomplete combustion of butane in oxygen is

$$C_4H_{10} + 4\tfrac{1}{2}O_2 \longrightarrow 4CO + 5H_2O$$

The volume in dm^3 of oxygen at 295 K and 100 kPa required to burn 0.1 mol of butane to form steam and carbon monoxide only is

A 8.6

B 11

C 12

D 16

14 Which one of the following does **not** have a major peak in its mass spectrum at $m/z = 43$?

A propanone

B butanone

C pentan-2-one

D pentan-3-one

15 Which one of the following does **not** have a singlet peak in its proton n.m.r. spectrum?

A butyl methanoate

B propyl ethanoate

C ethyl propanoate

D methyl butanoate

16 The relative molecular mass (M_r) of benzene-1,4-dicarboxylic acid is

A 164

B 166

C 168

D 170

17 Which one of the following is **not** a correct general formula for the non-cyclic compounds listed?

A alcohols $C_nH_{2n+2}O$

B aldehydes $C_nH_{2n+1}O$

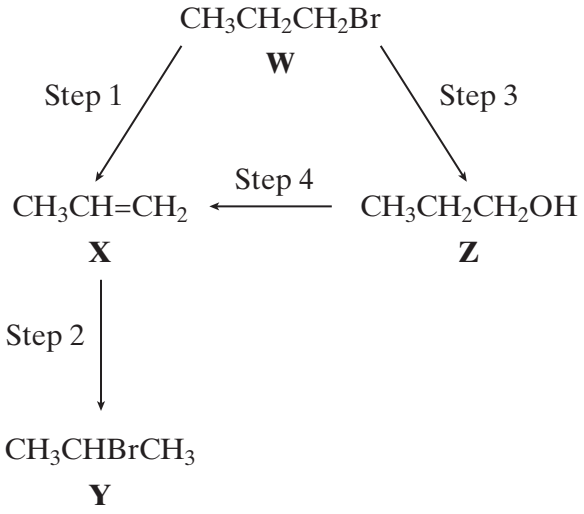
C esters $C_nH_{2n}O_2$

D primary amines $C_nH_{2n+3}N$

Turn over ▶

Questions 18 to 20

Questions **18** to **20** refer to the reaction scheme below.



18 Which one of the following statements is **not** correct?

A Reaction of **W** with sodium cyanide followed by hydrolysis of the resulting product gives propanoic acid.

B Mild oxidation of **Z** produces a compound that reacts with Tollens' reagent, forming a silver mirror.

C **Z** reacts with ethanoic acid to produce the ester propyl ethanoate.

D **X** undergoes addition polymerisation to form poly(propene).

19 Which one of the following reagents would **not** bring about the reaction indicated?

A Step 1 : alcoholic KOH

B Step 2 : aqueous Br_2

C Step 3 : aqueous NaOH

D Step 4 : concentrated H_2SO_4

20 Which one of the following statements is **not** correct?

A **W** and **Y** are structural isomers.

B **Z** is a primary alcohol.

C **Y** gives two peaks in its proton n.m.r. spectrum.

D **X** has geometrical isomers.

Multiple completion questions
For each of Questions **21** to **40**, **one or more** of the options given may be correct. Select your answer by means of the following code.

A if **1**, **2** and **3** only are correct.

B if **1** and **3** only are correct.

C if **2** and **4** only are correct.

D if **4** alone is correct.

Directions summarised			
A	**B**	**C**	**D**
1, **2** and **3** only correct	**1** and **3** only correct	**2** and **4** only correct	**4** only correct

Questions 21 and 22

Use the information below to answer Questions **21** and **22**.

Propanone reacts with iodine in acidic solution according to the following equation

$CH_3COCH_3(aq) + I_2(aq) \longrightarrow CH_3COCH_2I(aq) + H^+(aq) + I^-(aq)$

The rate equation for the formation of iodopropanone is found to be

$$rate = k[CH_3COCH_3(aq)][H^+(aq)]$$

21 Correct statements about this reaction include

1 the reaction is second order overall.

2 possible units for the rate are $mol^{-1}\,dm^3\,s^{-1}$

3 possible units for the rate constant are $mol^{-1}\,dm^3\,s^{-1}$

4 doubling the concentration of both reactants quadruples the rate.

22 Correct statements about this reaction include

1 the reaction rate increases if the temperature is raised.

2 the rate constant increases if the temperature is raised.

3 addition of a small amount of sodium hydroxide decreases the rate of this reaction.

4 the rate is doubled when the iodine concentration is doubled.

23 Molecules with a shape influenced by one or more lone pairs of electrons include

1 PF_5

2 CH_3NH_2

3 $CH_2{=}CH_2$

4 ClF_3

Turn over ▶

Directions summarised			
A	**B**	**C**	**D**
1, **2** and **3** only correct	**1** and **3** only correct	**2** and **4** only correct	**4** only correct

24 On melting, covalent bonds must break in

1 poly(ethene)

2 bromine

3 sulphur dioxide

4 silicon dioxide

25 Redox reactions include

1 $2CuCl + Cl_2 \longrightarrow 2CuCl_2$

2 $PCl_5 + 4H_2O \longrightarrow H_3PO_4 + 5HCl$

3 $Cl_2 + H_2O \longrightarrow HOCl + HCl$

4 $CH_3I + Cl^- \longrightarrow CH_3Cl + I^-$

26 Solutions with a pH of 1.0 include

1 $0.1\,mol\,dm^{-3}$ hydrochloric acid

2 $0.1\,mol\,dm^{-3}$ ethanoic acid

3 $0.05\,mol\,dm^{-3}$ sulphuric acid

4 $0.2\,mol\,dm^{-3}$ nitric acid

27 None of the following reactions is feasible at room temperature. Use your knowledge of entropy changes to deduce which will become feasible if the temperature is raised.

1 $2N_2(g) + O_2(g) \longrightarrow 2N_2O(g)$

2 $3O_2(g) \longrightarrow 2O_3(g)$

3 $2C(s) + 2H_2(g) \longrightarrow C_2H_4(g)$

4 $N_2(g) \longrightarrow 2N(g)$

Directions summarised			
A	**B**	**C**	**D**
1, **2** and **3** only correct	**1** and **3** only correct	**2** and **4** only correct	**4** only correct

28 A substitution reaction occurs when ammonia reacts with

1 $[Cu(H_2O)_6]^{2+}$

2 H_2O

3 CH_3Br

4 HBr

29 Processes in which the oxidation state of the metal in the complex ion is decreased include

1 $[Ag(CN)_2]^- \longrightarrow Ag$

2 $[Cr(H_2O)_6]^{3+} \longrightarrow Cr(OH)_3(H_2O)_3$

3 $[Ag(NH_3)_2]^+ \longrightarrow Ag$

4 $[Cr(H_2O)_6]^{3+} \longrightarrow [Cr(H_2O)_2Cl_4]^-$

30 Correct statements include

1 $AlCl_3$ can act as a Lewis acid in acylation reactions.

2 the shape of the BrF_4^- ion is square planar.

3 when aqueous silver nitrate and an excess of aqueous ammonia are added to aqueous sodium iodide, a yellow precipitate is formed.

4 the boiling point of bromine is lower than that of iodine because the Br–Br bond is weaker than the I–I bond.

Directions summarised			
A	**B**	**C**	**D**
1, **2** and **3** only correct	**1** and **3** only correct	**2** and **4** only correct	**4** only correct

31 Reactions in which the same element undergoes simultaneous oxidation and reduction include

1 $Cl_2 + H_2O \longrightarrow HCl + HClO$

2 $Cl_2 + SO_2 + 2H_2O \longrightarrow H_2SO_4 + 2HCl$

3 $3MnO_4^{2-} + 4H^+ \longrightarrow 2MnO_4^- + MnO_2 + 2H_2O$

4 $14HI + 2H_2SO_4 \longrightarrow 7I_2 + S + H_2S + 8H_2O$

32 Correct statements about chloride ions include

1 they have the electronic configuration of $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

2 they are formed in the reaction of chlorine with potassium bromide solution.

3 they form a white precipitate with silver nitrate solution that dissolves on addition of dilute aqueous ammonia.

4 they form a cobalt(II) complex that has an octahedral shape.

33 Correct statements about H_2NCH_2COOH include

1 it can act as a Lewis base.

2 it forms an approximately neutral solution in water.

3 it can form condensation polymers.

4 it can be made from $BrCH_2COOH$ by reaction with KCN followed by reduction.

34 A compound, **X**, has the following composition by mass:

40.00% carbon, 6.67% hydrogen, 53.33% oxygen.

Which of the following compounds could be **X**?

1 methanal

2 2-hydroxypropanoic acid

3 ethanoic acid

4 epoxyethane

Directions summarised			
A	**B**	**C**	**D**
1, **2** and **3** only correct	**1** and **3** only correct	**2** and **4** only correct	**4** only correct

35 The compound $CH_3CH(OH)CH_2COOCH_3$ is found in marshmallows. Correct statements about this compound include

1 its systematic name is ethyl 2-hydroxybutanoate.

2 it has one chiral centre.

3 it has an absorption in its infra-red spectrum at $2750\,cm^{-1}$

4 it turns warm acidified potassium dichromate(VI) from orange to green.

36 A carbocation is involved in

1 the reaction of chloroethane with benzene in the presence of aluminium chloride.

2 the cracking of $C_{16}H_{34}$ with a zeolite catalyst.

3 the fragmentation of butanone in the mass spectrometer.

4 the reduction of propanal with sodium tetrahydridoborate(III) ($NaBH_4$)

37 Pairs of functional group isomers include

1 $CH_3CH_2CH_2CH_2NO_2$ and $CH_3CH_2CH(NH_2)COOH$

2 $HOCH_2CH_2CH_2CHO$ and $CH_3COCH_2CH_2OH$

3 $H_2NCH_2CH_2CH_2COOH$ and $H_2NCH_2COOCH_2CH_3$

4 $CH_3CH_2CH{=}CH_2$ and $CH_3CH{=}CHCH_3$

38 Compounds which have stereoisomers include

1 $ClCH_2CH(CH_3)CH_2CH_2Cl$

2 $(CH_3)_2C{=}CHCH_2Cl$

3 $CH_3CHClCH_2CH_2CH_2Cl$

4 $(CH_3)_2CHCH{=}CCl_2$

Directions summarised			
A	**B**	**C**	**D**
1, **2** and **3** only correct	**1** and **3** only correct	**2** and **4** only correct	**4** only correct

39 Refer to the following reaction sequence

$$(CH_3)_2CHCH_2CH_3 \rightarrow (CH_3)_2CClCH_2CH_3 \rightarrow (CH_3)_2C(OH)CH_2CH_3 \rightarrow (CH_3)_2C{=}CHCH_3$$

$$\downarrow$$

$$(CH_3)_2C(CH_2NH_2)CH_2CH_3 \leftarrow (CH_3)_2C(CN)CH_2CH_3 \leftarrow (CH_3)_2CBrCH_2CH_3$$

Types of reaction mechanism involved in the above sequence include

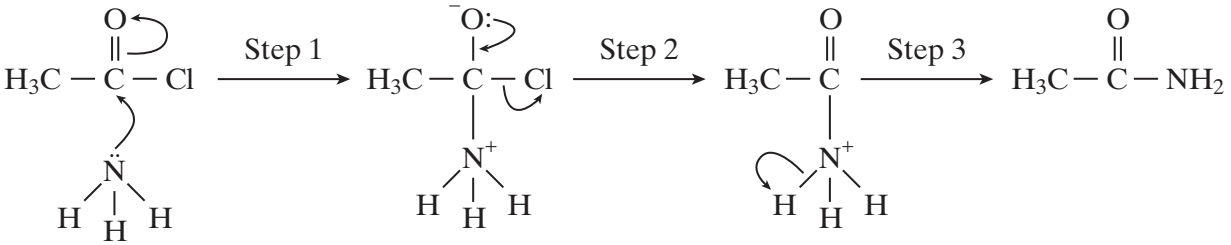
1 electrophilic addition.

2 nucleophilic substitution.

3 free-radical substitution.

4 nucleophilic addition–elimination.

40 A mechanism for the reaction between ammonia and ethanoyl chloride is given below.



Correct statements include

1 the ammonia behaves as a nucleophile.

2 the proton loss in step 3 has been shown incorrectly.

3 the ammonia attacks an electron-deficient carbon atom.

4 this mechanism is called nucleophilic substitution.

END OF QUESTIONS