Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

General Certificate of Education
January 2005
Advanced Level Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

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

Tuesday 25 January 2005 Afternoon 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

Questions **1** and **2** are about the reaction given below.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

Enthalpy data for the reacting species are given in the table below.

Substance	CO(g)	$H_2O(g)$	$CO_2(g)$	$H_2(g)$
$\Delta H_f^{\ominus}$/kJ mol^{-1}	–110	–242	–394	0

1 The standard enthalpy change for this reaction of carbon monoxide and steam is

A +42 kJ mol^{-1}

B –42 kJ mol^{-1}

C +262 kJ mol^{-1}

D –262 kJ mol^{-1}

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

A The value of K_p changes when the temperature changes.

B The activation energy decreases when the temperature is increased.

C The entropy change is more positive when the water is liquid rather than gaseous.

D The enthalpy change is more positive when the water is liquid rather than gaseous.

Turn over ▶

3 Use the information below to answer this question.

$$C(s) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H^{\ominus} = -394\,kJ\,mol^{-1}$$

$$H_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow H_2O(l) \qquad \Delta H^{\ominus} = -286\,kJ\,mol^{-1}$$

$$4C(s) + 5H_2(g) \longrightarrow C_4H_{10}(g) \qquad \Delta H^{\ominus} = -126\,kJ\,mol^{-1}$$

The standard enthalpy of combustion of butane, in $kJ\,mol^{-1}$, is

A –2880

B –2590

C –806

D –554

4 Chlorine has two isotopes, ^{35}Cl and ^{37}Cl. The number of molecular ion peaks in the mass spectrum of a sample of Cl_2 is

A 2

B 3

C 4

D 5

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

A The first ionisation energy of iron is greater than its second ionisation energy.

B The magnitude of the lattice enthalpy of magnesium oxide is greater than that of barium oxide.

C The oxidation state of iron in $[Fe(CN)_6]^{3-}$ is greater than the oxidation state of copper in $[CuCl_2]^-$

D The boiling point of C_3H_8 is lower than that of CH_3CH_2OH

Questions 6 and 7

In questions **6** and **7** consider the data below.

	$E^{\ominus}$/V
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	−0.13

6 The e.m.f. of the cell $Ag(s)|Ag^+(aq)||Pb^{2+}(aq)|Pb(s)$ is

A 0.93 V

B 0.67 V

C −0.67 V

D −0.93 V

7 The e.m.f. of the cell $Pt(s)|H_2(g)|H^+(aq)||Ag^+(aq)|Ag(s)$ would be increased by

A increasing the concentration of $H^+(aq)$.

B increasing the surface area of the Pt electrode.

C increasing the concentration of $Ag^+(aq)$.

D decreasing the pressure of $H_2(g)$.

TURN OVER FOR THE NEXT QUESTION

8 Which one of the following reactions will **not** occur?

A $Al(OH)_3(s) + 3OH^-(aq) \longrightarrow [Al(OH)_6]^{3-}(aq)$

B $Al(OH)_3(s) + 3H^+(aq) + 3H_2O(l) \longrightarrow [Al(H_2O)_6]^{3+}(aq)$

C $8HBr(g) + H_2SO_4(l) \longrightarrow 4Br_2(g) + H_2S(g) + 4H_2O(l)$

D $AgBr(s) + 2S_2O_3^{2-}(aq) \longrightarrow [Ag(S_2O_3)_2]^{3-}(aq) + Br^-(aq)$

9 A 0.0720 g sample of reducing agent **R** was dissolved in water and acidified with an excess of dilute H_2SO_4. The resulting solution was found to react with exactly 18.0 cm^3 of a 0.0200 mol dm^{-3} solution of $KMnO_4$.

In this reaction, 5 mol of **R** react with 3 mol of $KMnO_4$. The M_r of **R** is

A 120

B 167

C 240

D 333

10 Which one of the following pairs forms a white precipitate when mixed?

A NaCl(aq) and NaOH(aq)

B $CuSO_4$(aq) and $BaCl_2$(aq)

C KF(aq) and $AgNO_3$(aq)

D $CoCl_2$(aq) and Na_2CO_3(aq)

11 A disproportionation reaction occurs when a species $\mathbf{M^+}$ spontaneously undergoes simultaneous oxidation and reduction.

$$2M^+(aq) \longrightarrow M^{2+}(aq) + M(s)$$

The table below contains $E^{\ominus}$ data for copper and mercury species.

	$E^{\ominus}$/V
$Cu^{2+}(aq) + e^- \longrightarrow Cu^+(aq)$	+ 0.15
$Cu^+(aq) + e^- \longrightarrow Cu(s)$	+ 0.52
$Hg^{2+}(aq) + e^- \longrightarrow Hg^+(aq)$	+ 0.91
$Hg^+(aq) + e^- \longrightarrow Hg(l)$	+ 0.80

Using these data, which one of the following can be predicted?

A Both Cu(I) and Hg(I) undergo disproportionation.

B Only Cu(I) undergoes disproportionation.

C Only Hg(I) undergoes disproportionation.

D Neither Cu(I) nor Hg(I) undergoes disproportionation.

12 The vanadium does **not** have an oxidation state of +3 in

A $[V(H_2O)_6]^{3+}$

B $[V(C_2O_4)_3]^{3-}$

C $[V(OH)_3(H_2O)_3]$

D $[VCl_4]^{3-}$

Turn over ▶

13 In which one of the following mixtures does a redox reaction occur?

A ethanal and Tollens' reagent

B ethanoyl chloride and ethanol

C ethanal and hydrogen cyanide

D ethanoic acid and sodium hydroxide

14 The percentage by mass of carbon is 83.3% in

A propane.

B butane.

C pentane.

D hexane.

15 Propanone can be reduced to form an alcohol. A functional group isomer of the alcohol formed is

A $CH_3CH_2CH_2OH$

B CH_3CH_2CHO

C $CH_3OCH_2CH_3$

D CH_3COCH_3

16 Propanoic acid reacts with methanol in the presence of a small amount of concentrated sulphuric acid. The empirical formula of the ester formed is

A CH_2O

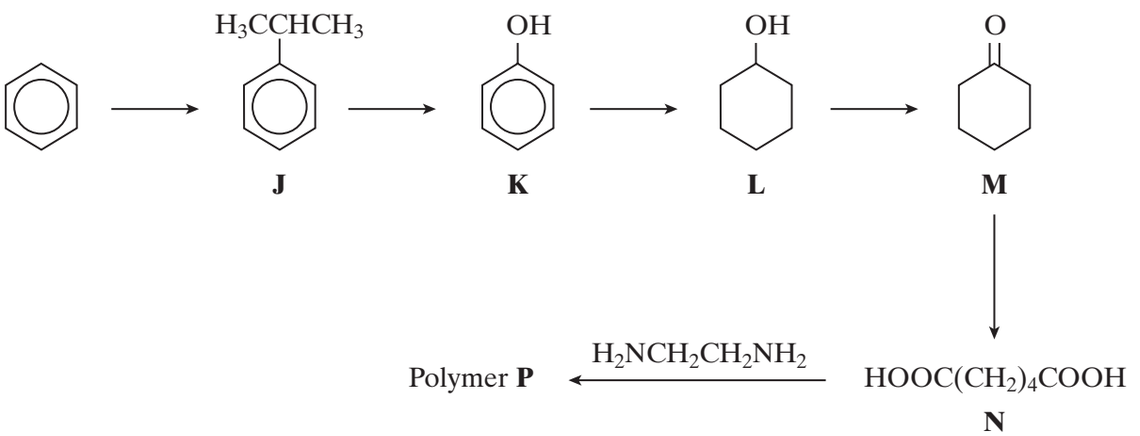
B $C_2H_6O_2$

C $C_2H_4O_2$

D C_2H_4O

Questions 17 to 20

Questions **17** to **20** are about the following reaction scheme which shows the preparation of polymer **P**.



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

A The conversion of benzene into **J** is alkylation.

B The mechanism for the conversion of benzene into **J** is electrophilic substitution.

C The conversion of **K** into **L** is oxidation.

D The conversion of **L** into **M** is oxidation.

18 If 1.0 kg of benzene gave 0.98 kg of **J**, the percentage yield of **J** was

A 64

B 66

C 68

D 70

19 **K** is a weak acid with a pK_a of 9.95. The pH of a 0.10 mol dm^{-3} solution of **K** is

A 4.48

B 4.98

C 5.48

D 5.98

20 Polymer **P** is formed in a two-step reaction from **N**. The first stage is a neutralisation reaction. The volume, in cm^3, of a $0.20\,mol\,dm^{-3}$ solution of $H_2NCH_2CH_2NH_2$ required to neutralise 6.8×10^{-3} mol of the acid **N** is

A 17

B 34

C 68

D 136

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** only 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

In the presence of a catalyst, methanol can be synthesised from carbon monoxide and hydrogen according to the equation

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

Thermodynamic data are given below.

Substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$S^{\ominus}$ / J K^{-1} mol^{-1}
CO(g)	–110	198
H_2(g)	0	131
CH_3OH(g)	–201	240

21 Correct statements about this reaction at 300 K include

1 the standard enthalpy change is −91 kJ mol^{-1}.

2 the standard entropy change is −220 J K^{-1} mol^{-1}.

3 the standard free-energy change is −25 kJ mol^{-1}.

4 the reaction is not feasible at temperatures below 42 K.

22 The yield of this reaction is increased by

1 a decrease in pressure.

2 liquefying the product.

3 the addition of a catalyst.

4 a decrease in temperature.

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

23 Processes accompanied by a decrease in entropy include

1 the formation of ammonia from nitrogen and hydrogen.

2 the melting of ice.

3 the formation of N_2O_4 gas from NO_2 gas.

4 the reaction of ethanedioate ions with $Cu^{2+}(aq)$ ions.

24 Correct statements include

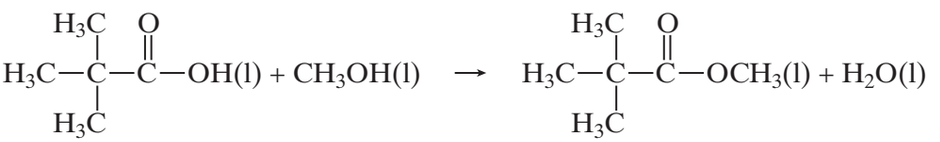
1 Na atoms are larger than Mg atoms.

2 Mg^{2+} ions are smaller than Na^+ ions.

3 S atoms are larger than Cl atoms.

4 Cl^- ions are larger than S^{2-} ions.

25 Consider the following conversion.



T **U**

Correct statements about this conversion include

1 the entropy change in the reaction is likely to be small.

2 the enthalpy change in the reaction is likely to be small.

3 the reaction is catalysed by acids.

4 if 1 g of **T** gives 1 g of **U** the yield for the conversion is 100%.

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

26 Redox reactions include

1 $2CrO_4^{2-} + 2H^+ \longrightarrow Cr_2O_7^{2-} + H_2O$

2 $Cl_2 + 2OH^- \longrightarrow Cl^- + ClO^- + H_2O$

3 $I^- + H_2SO_4 \longrightarrow HI + HSO_4^-$

4 $S_2O_8^{2-} + 2I^- \longrightarrow I_2 + 2SO_4^{2-}$

27 Substances that form an alkaline solution in water include

1 P_2O_5

2 CaO

3 $HOCH_2CH_2OH$

4 CH_3NH_2

28 For which of the following substances will 0.125 mol of oxygen be enough for complete combustion?

1 0.21 mol of magnesium

2 0.19 mol of aluminium

3 0.12 mol of carbon

4 0.075 mol of methane

29 Structures with a central atom having a co-ordination number of 6 and an oxidation state of +2 include

1 $[Cu(C_2O_4)_3]^{4-}$

2 $[Co(CN)_5(H_2O)]^{3-}$

3 $[Ni(EDTA)]^{2-}$

4 $[Fe(CN)_6]^{3-}$

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

30 The types of bonding in methylammonium chloride include

1 ionic.

2 co-ordinate.

3 covalent.

4 hydrogen.

31 Methylamine reacts with

1 ethene.

2 ethanoyl chloride.

3 benzene.

4 bromoethane.

32 Possible products formed when methylamine reacts with aqueous cobalt(II) chloride include

1 $[Co(CH_3NH_2)_6]^{2+}$

2 $[Co(CH_3NH_3Cl)_6]^{2+}$

3 $[Co(CH_3NH_2)_2(H_2O)_4]^{2+}$

4 $[Co(CH_3NH_3)_6]^{2+}$

33 A major peak at m/z = 43 occurs in the mass spectrum of

1 pentan-3-one.

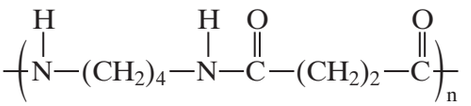
2 pentan-2-one.

3 2-methylpentan-3-one.

4 phenylethanone.

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

34 The repeating unit of a polymer is shown below.



This polymer has

1 van der Waals' forces.

2 hydrogen bonding.

3 dipole-dipole attractions.

4 ionic bonding.

35 Values that show an increase from left to right include

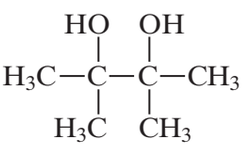
1 the boiling points of CH_3COCH_3, CH_3COOH and H_2NCH_2COOH

2 the boiling points of $CH_3CH_2CH_2CH_2CH_3$, $(CH_3)_2CHCH_2CH_3$ and $(CH_3)_4C$

3 the n.m.r. δ values of the underlined protons in $Si(C\underline{H}_3)_4$, $CH_3CH_2C\underline{H}_3$ and $CH_3COOC\underline{H}_3$

4 the bond angles in CH_4, NH_3 and H_2O

36 Correct statements about the following compound include



1 it exists as a pair of stereoisomers.

2 it has an absorption in the infrared at about $3350\,cm^{-1}$.

3 it can be oxidised with acidified potassium dichromate(VI).

4 it can form hydrogen bonds.

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

37 Compounds with two singlets in the proton n.m.r. spectrum include

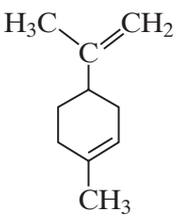
1 ethane.

2 ethanoic acid.

3 ethanol.

4 ethane-1,2-diol.

38 Limonene has the structure shown below.



Correct statements about limonene include

1 it has an empirical formula of C_5H_8

2 it has van der Waals' forces between its molecules.

3 one mole of limonene reacts with two moles of hydrogen bromide.

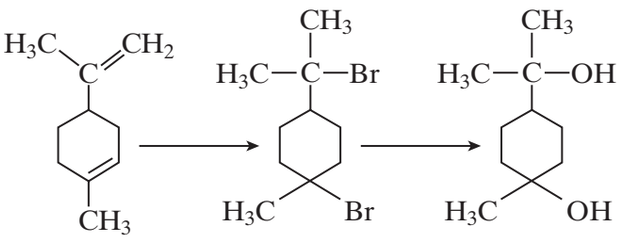
4 one mole of limonene requires four moles of hydrogen gas to become completely saturated.

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 39 and 40

Use the information below to answer questions **39** and **40**

Limonene, which occurs in citrus fruits, belongs to a class of natural products called terpenes. The conversion of limonene into compound **X**, via a bromoalkane intermediate, is shown below. Compound **X** can be used in cough medicine.



Limonene | Bromoalkane intermediate | **X**

39 Types of mechanism shown in the reactions above include

1 electrophilic addition.

2 nucleophilic addition.

3 nucleophilic substitution.

4 electrophilic substitution.

40 Correct statements about compound **X** include

1 it exhibits hydrogen bonding between its molecules.

2 it is dehydrated by hot concentrated sulphuric acid.

3 it reacts with ethanoyl chloride to produce an ester.

4 it is oxidised by acidified potassium dichromate(VI).

END OF QUESTIONS

THERE ARE NO QUESTIONS PRINTED ON THIS PAGE