Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

General Certificate of Education
January 2004
Advanced Level Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

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

Friday 23 January 2004 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
- 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 **24** 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 to 3

The data below refer to the industrial production of nitric acid from ammonia. Use this information to answer questions **1** to **3**.

Reaction 1 $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$ $\Delta H^{\ominus} = -909\,kJ\,mol^{-1}$

Reaction 2 $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ $\Delta H^{\ominus} = -115\,kJ\,mol^{-1}$

Reaction 3 $3NO_2(g) + H_2O(l) \rightleftharpoons 2HNO_3(aq) + NO(g)$ $\Delta H^{\ominus} = -117\,kJ\,mol^{-1}$

1 Possible units for the equilibrium constant, K_c, for *reaction 2* are

A $mol^{-2}\,m^6$

B $mol^{-1}\,dm^3$

C no units

D $mol\,dm^{-3}$

2 The equilibrium yield in **all three** reactions is increased when

A the pressure is increased.

B the pressure is decreased.

C the temperature is increased.

D the temperature is decreased.

3 The direct oxidation of ammonia to nitrogen dioxide can be represented by the equation

$$4NH_3(g) + 7O_2(g) \rightarrow 4NO_2(g) + 6H_2O(g)$$

for which the standard enthalpy change, in $kJ\,mol^{-1}$, is

A −1139

B −1024

C −794

D −679

Turn over ▶

4 Sodium hydrogencarbonate decomposes on heating as shown by the equation below.

$$2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$$

The volume of carbon dioxide, measured at 298 K and 101 kPa, obtained by heating 0.0500 mol of sodium hydrogencarbonate is

A 613 cm^3

B 1226 cm^3

C 613 dm^3

D 1226 dm^3

Questions 5 to 8

Questions **5** to **8** refer to ethanedioic acid, $(COOH)_2$.
This is a diprotic acid with K_a values of 5.9×10^{-2} mol dm^{-3} and 5.3×10^{-5} mol dm^{-3}.

5 The pH of a 0.0010 mol dm^{-3} solution of ethanedioic acid is
(For this calculation, you should neglect the second ionisation.)

A 1.23

B 2.11

C 4.23

D 4.28

6 The minimum volume of a 0.150 mol dm^{-3} solution of sodium hydroxide required to neutralise 0.00500 mol of ethanedioic acid completely is

A 33.3 cm^3

B 50.0 cm^3

C 66.7 cm^3

D 300 cm^3

7 Which one of the following reactions would **not** lead to the formation of ethanedioic acid?

A oxidation of $HOCH_2CH_2OH$

B oxidation of HOOCCHO

C hydrolysis of $NCCH_2CH_2CN$

D hydrolysis of $CH_3OOCCOOCH_3$

8 Which one of the following is **not** correct?

A Ethanedioic acid produces bubbles of gas when treated with aqueous sodium hydrogencarbonate.

B The ethanedioate ion can form octahedral complex ions with transition metal ions.

C A buffer solution is formed when a $0.1\,mol\,dm^{-3}$ aqueous solution of the acid is mixed with an equal volume of a $0.05\,mol\,dm^{-3}$ solution of sodium hydroxide.

D When an aqueous solution of ethanedioic acid is titrated with sodium hydroxide, a suitable indicator for the first equivalence point is phenolphthalein.

9 Which one of the following is a redox reaction?

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

B $3Cl_2 + 6OH^- \longrightarrow 5Cl^- + ClO_3^- + 3H_2O$

C $HNO_3 + 2H_2SO_4 \longrightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$

D $CaCO_3 + SiO_2 \longrightarrow CaSiO_3 + CO_2$

TURN OVER FOR THE NEXT QUESTION

Questions 10 and 11

Use the data in the table below to answer questions **10** and **11**.

	$E^{\ominus}$/V
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$	+ 1.52
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	+ 1.33
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+ 0.77
$Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$	– 0.41
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	– 0.76

10 The most powerful oxidising agent in the table is

A $Mn^{2+}(aq)$

B $Zn(s)$

C $MnO_4^-(aq)$

D $Zn^{2+}(aq)$

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

A $Fe^{2+}(aq)$ can reduce acidified $MnO_4^-(aq)$ to $Mn^{2+}(aq)$

B $Cr_2O_7^{2-}(aq)$ can oxidise acidified $Fe^{2+}(aq)$ to $Fe^{3+}(aq)$

C $Zn(s)$ can reduce acidified $Cr_2O_7^{2-}(aq)$ to $Cr^{2+}(aq)$

D $Fe^{2+}(aq)$ can reduce acidified $Cr^{3+}(aq)$ to $Cr^{2+}(aq)$

Questions 12 to 14

Use the information below to answer questions **12** to **14**.

A saturated solution of magnesium hydroxide, $Mg(OH)_2$, contains 0.1166 g of $Mg(OH)_2$ in 10.00 dm^3 of solution. In this solution the magnesium hydroxide is fully dissociated into ions.

12 Which one of the following is the concentration of $Mg^{2+}(aq)$ ions in the saturated solution?

A $2.82 \times 10^{-2}\,mol\,dm^{-3}$

B $2.00 \times 10^{-3}\,mol\,dm^{-3}$

C $2.82 \times 10^{-3}\,mol\,dm^{-3}$

D $2.00 \times 10^{-4}\,mol\,dm^{-3}$

13 Which one of the following is the pH of a solution of magnesium hydroxide containing $4.0 \times 10^{-5}\,mol\,dm^{-3}$ of hydroxide ions at 298 K?
($K_w = 1.0 \times 10^{-14}\,mol^2\,dm^{-6}$ at 298 K)

A 9.6

B 9.5

C 8.6

D 8.3

14 The equilibrium constant expression for the dissolving of magnesium hydroxide is $K = [Mg^{2+}]\,[OH^-]^2$. In a saturated solution of $Mg(OH)_2$ at a different temperature, the concentration of hydroxide ions is $1.0 \times 10^{-3}\,mol\,dm^{-3}$.

Which one of the following has the correct value and units for K under these conditions?

A $1.0 \times 10^{-6}\,mol^2\,dm^{-6}$

B $5.0 \times 10^{-7}\,mol^2\,dm^{-6}$

C $1.0 \times 10^{-9}\,mol^3\,dm^{-9}$

D $5.0 \times 10^{-10}\,mol^3\,dm^{-9}$

Turn over ▶

15 A particular sample of bauxite ore contains 55% by mass of Al_2O_3 (M_r = 102) and no other aluminium compound. The minimum mass of this ore needed to produce 1.0 tonne of aluminium is

A 1.8 tonne

B 1.9 tonne

C 2.9 tonne

D 3.4 tonne

16 Use your knowledge of the chemistry of transition metals to predict which of the following will convert $[Mn(H_2O)_6]^{2+}$ into MnO_4^{2-}

A an acid and a reducing agent

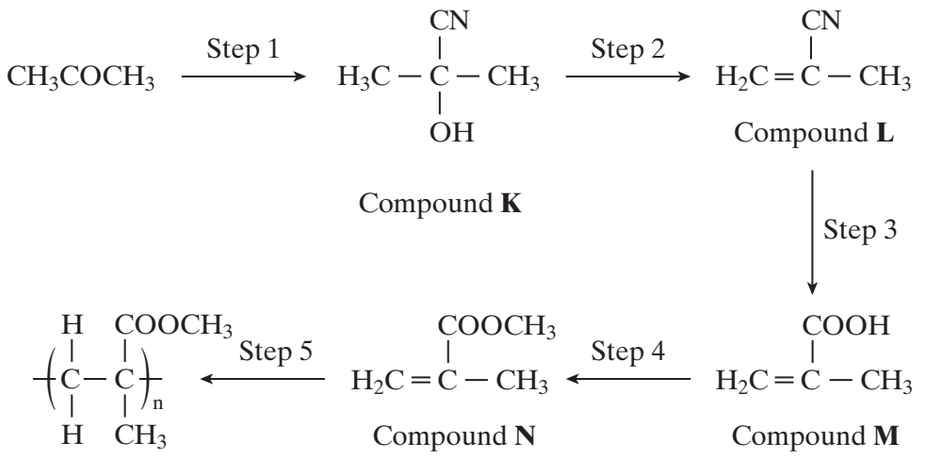
B an acid and an oxidising agent

C an alkali and a reducing agent

D an alkali and an oxidising agent

Questions 17 and 18

Questions **17** and **18** concern the preparation of the plastic poly(methyl 2-methylpropenoate) (*Perspex*), starting from propanone.



17 Which one of the following sets of reagents is **not** suitable for the step indicated?

A Step 1 HCN (NaCN then dilute HCl)

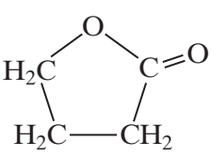
B Step 2 hot ethanolic KOH

C Step 3 warm aqueous H_2SO_4

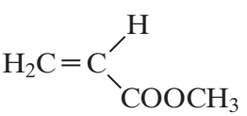
D Step 4 CH_3OH with an acid catalyst

18 Which one of the following is **not** a structural isomer of Compound **M**?

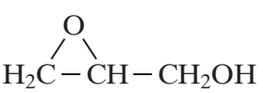
A



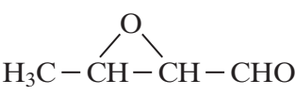
B



C



D



Turn over ▶

19 Terylene is made by reacting benzene-1,4-dicarboxylic acid and ethane-1,2-diol.

Terylene is

A an addition polymer.

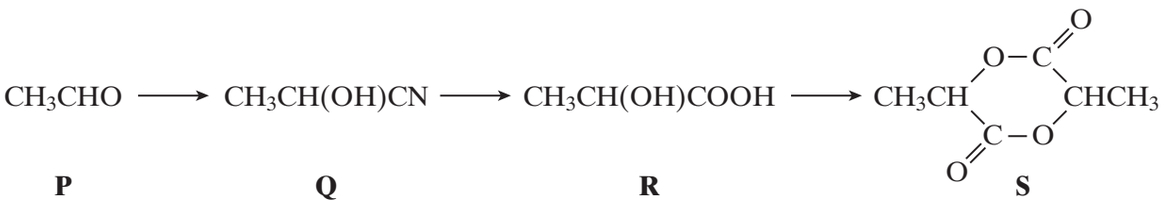
B a polyamide.

C a polyester.

D a nylon.

Questions 20 to 22

Questions **20** to **22** refer to the reaction sequence below.



P **Q** **R** **S**

20 Which one of the following is **not** involved in the reaction sequence?

A esterification

B hydrolysis

C nucleophilic addition

D reduction

21 HCN is a weak acid with a pK_a value of 9.40. If a 0.010 mol dm^{-3} solution of HCN was used in the first step, the concentration of cyanide ions, in mol dm^{-3}, would be

A 2.0×10^{-6}

B 6.4×10^{-5}

C 2.0×10^{-5}

D 3.1×10^{-1}

22 Which one of the following statements about compounds **P** to **S** is **not** correct?

A **P**, **Q**, **R** and **S** all have a strong absorption in their infra-red spectra between 1700 and 1750 cm^{-1}

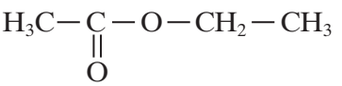
B **P** and **S** both have two peaks in their proton n.m.r. spectra with areas in the ratio 3:1

C **P**, **Q**, **R** and **S** all have doublet peaks in their proton n.m.r. spectra that can be assigned to a methyl group.

D **S** has major peaks in the mass spectrum at m/z = 144 and 129

Turn over ▶

23 Which one of the following does **not** support the suggestion that an unknown organic compound could be



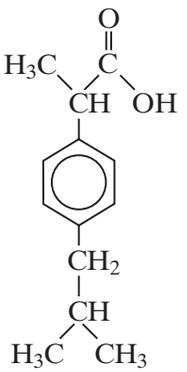
A It has elemental composition by mass of O, 36.36%; H, 9.09%

B Its mass spectrum has major peaks at m/z = 88 and 57 and 31

C Its infra-red spectrum has an absorption at 1735 cm^{-1}

D Its proton n.m.r. spectrum has 3 peaks, in the area ratio 2:3:3

24 Ibuprofen is a drug used as an alternative to aspirin for the relief of pain, fever and inflammation. The structure of ibuprofen is shown below.



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

A It has optical isomers.

B It liberates carbon dioxide with sodium carbonate solution.

C It undergoes esterification with ethanol.

D It undergoes oxidation with acidified potassium dichromate(VI).

Multiple completion questions
For each of Questions **25** 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

25 Reactions with a positive value for ΔS include

1 fermentation of glucose.

2 hydration of ethene.

3 hydrolysis of ethanoyl chloride.

4 polymerisation of propene.

26 Correct statements include

1 $Be(OH)_2$ is amphoteric.

2 $Ba(OH)_2$ is more soluble in water than $Ca(OH)_2$

3 CH_3COCl will give a white precipitate when added to aqueous silver nitrate.

4 $CoCl_2$ and concentrated hydrochloric acid form the $[CoCl_6]^{4-}(aq)$ ion.

27 Redox reactions include

1 $C_2H_4(g) + H_2(g) \longrightarrow C_2H_6(g)$

2 $2H_2O_2(aq) \longrightarrow 2H_2O(l) + O_2(g)$

3 $3C_2H_5OH(l) + 2Cr_2O_7^{2-}(aq) + 16H^+(aq) \longrightarrow 3CH_3COOH(aq) + 4Cr^{3+}(aq) + 11H_2O(l)$

4 $N_2O_4(g) \longrightarrow 2NO_2(g)$

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

28 The extraction of titanium can be represented by the following equations:

Reaction 1 $TiO_2 + 2Cl_2 + 2C \longrightarrow TiCl_4 + 2CO$

Reaction 2 $TiCl_4 + 4Na \longrightarrow Ti + 4NaCl$

Correct statements include

1 Both reactions are redox reactions.

2 An argon atmosphere is used in *reaction 2*.

3 0.52 tonne of titanium can be produced by using 1.0 tonne of sodium.

4 0.48 tonne of sodium is needed to produce 1.0 tonne of titanium.

29 Consider the Period 3 elements

Na, Mg, Al, Si, P, S, Cl

Correct statements include

1 Na(g) has the largest atomic radius.

2 Na(s) has the highest electrical conductivity.

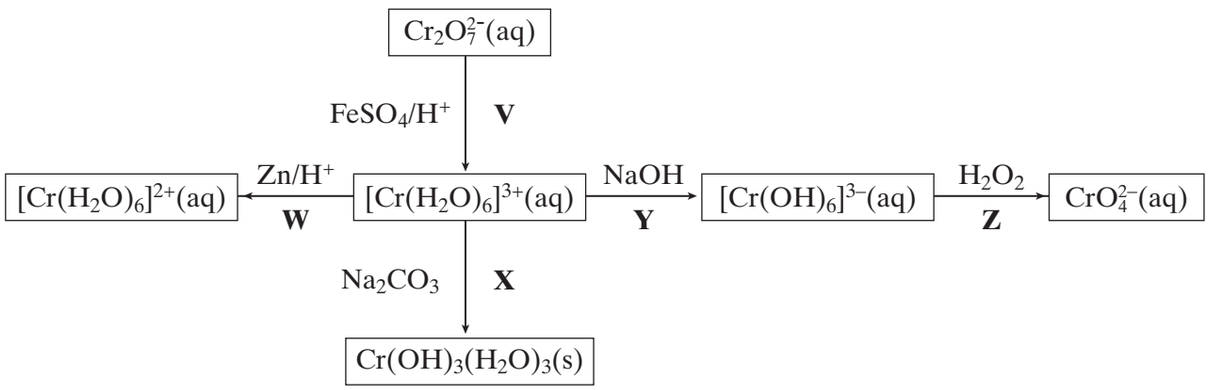
3 Cl(g) has the highest first ionisation enthalpy.

4 $Cl^-(g)$ and $S^{2-}(g)$ have the same ionic radius.

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 30 to 32

In questions **30** to **32** consider the reaction scheme below.



30 Correct statements include

1 sodium carbonate is an oxidising agent in step **X**.

2 zinc is a reducing agent in step **W**.

3 iron(II) sulphate is an oxidising agent in step **V**.

4 hydrogen peroxide is an oxidising agent in step **Z**.

31 Correct statements include

1 the oxidation states of chromium shown in the above reaction scheme are +2, +3 and +6.

2 only step **X** will produce a precipitate and a gas.

3 steps **V**, **W** and **Z** will produce a colour change.

4 steps **X** and **Y** will involve a change in the oxidation state of chromium.

32 Correct equations for the steps above include

1 $Cr_2O_7^{2-} + 14H^+ + 3Fe^{2+} \rightarrow 2Cr^{3+} + 3Fe^{3+} + 7H_2O$

2 $Zn + [Cr(H_2O)_6]^{3+} \rightarrow [Cr(H_2O)_6]^{2+} + Zn^{2+}$

3 $3[Cr(H_2O)_6]^{3+} + 2CO_3^{2-} \rightarrow 3[Cr(OH)_3(H_2O)_3] + 2CO_2 + 2H_2O$

4 $2[Cr(OH)_6]^{3-} + 3H_2O_2 \rightarrow 2CrO_4^{2-} + 2OH^- + 8H_2O$

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

33 Correct statements about the complex $[Co(H_2NCH_2CH_2NH_2)_3]^{3+}$ include

1 the ligand in the complex is bidentate.

2 the oxidation state of cobalt in the complex is +3.

3 the complex has an octahedral shape.

4 the coordination number of cobalt in the complex is 3.

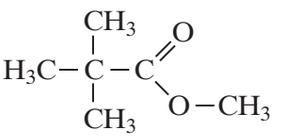
34 Correct statements about 2-methylbutanal include

1 it reduces $[Ag(NH_3)_2]^+$ to silver.

2 it has stereoisomers.

3 it has a strong absorption in its infra-red spectrum at about 1705 cm^{-1}.

4 its proton n.m.r. spectrum includes only one peak that can be assigned to a methyl group.

35 Correct statements about  include

1 it is an isomer of ethyl pentanoate.

2 it has major peaks at m/z = 57 and 85 in its mass spectrum.

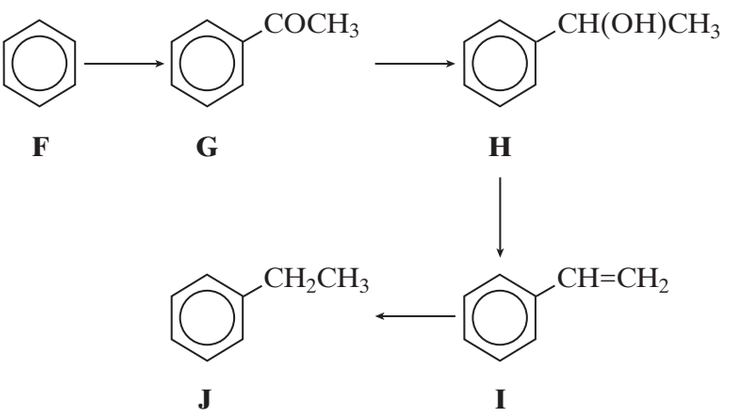
3 it has three singlet peaks in its proton n.m.r. spectrum with area ratio 6:3:3

4 hydrolysis gives an organic product with a broad absorption in the infra-red at 3350 cm^{-1}.

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 36 and 37

Questions **36** and **37** are about the reaction sequence below.



36 Conversions that are reductions include

1 **F** into **G**

2 **G** into **H**

3 **H** into **I**

4 **I** into **J**

37 Correct statements include

1 ethanoyl chloride with a Lewis acid could achieve the conversion of **F** into **G**.

2 **G** would show major peaks in its mass spectrum at m/z = 115 and 43.

3 the conversion of **H** into **I** could be achieved with concentrated sulphuric acid; this is an example of homogeneous catalysis.

4 the proton n.m.r. spectrum of **J** includes a triplet and a quartet in the area ratio 2:3, respectively.

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

38 Correct statements about non-cyclic compounds include

1 there are two geometrical isomers of C_3H_5Cl

2 there are two position isomers of C_3H_7Cl

3 there are two optical isomers of $C_3H_6Cl_2$

4 there are two chain isomers of C_3H_8

39 Types of reaction that the molecule below can undergo include

1 electrophilic addition and nucleophilic addition.

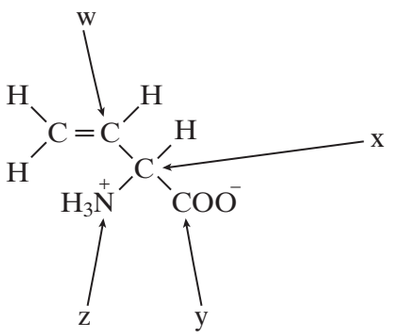
2 electrophilic substitution and nucleophilic substitution.

3 electrophilic addition and electrophilic substitution.

4 nucleophilic addition and nucleophilic substitution.

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

40 Atoms around which the bonds are arranged tetrahedrally include



1 atom w

2 atom x

3 atom y

4 atom z

END OF QUESTIONS