Surname		Other Names	
Centre Number			Candidate Number				
Candidate Signature									

General Certificate of Education
January 2003
Advanced Level Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

CHEMISTRY CHM6/W
Unit 6a Synoptic Assessment

Friday 24 January 2003 Afternoon Session

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

Time allowed: 1 hour

Instructions
- Use a blue or 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 $R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$

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.

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 **21** 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 5

Questions **1** to **5** relate to the equilibrium gas-phase synthesis of sulphur trioxide:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Thermodynamic data for the components of this equilibrium are:

Substance	$\Delta H_f^{\ominus}$/kJ mol^{-1}	$S^{\ominus}$/J K^{-1} mol^{-1}
$SO_3(g)$	–396	+257
$SO_2(g)$	–297	+248
$O_2(g)$	0	+204

This equilibrium, at a temperature of 585 K and a total pressure of 540 kPa, occurs in a vessel of volume 1.80 dm^3. At equilibrium, the vessel contains 0.0500 mol of $SO_2(g)$, 0.0800 mol of $O_2(g)$ and 0.0700 mol of $SO_3(g)$.

1 The mole fraction of SO_3 in the equilibrium mixture is

A 0.250

B 0.350

C 0.440

D 0.700

2 With pressures expressed in MPa units, the value of the equilibrium constant, K_p, is

A 4.90

B 6.48

C 9.07

D 16.8

3 Possible units for the equilibrium constant K_p include

A no units

B kPa

C MPa^{-1}

D kPa^{-2}

4 The standard entropy change for this reaction is

A $-222\,J\,K^{-1}\,mol^{-1}$

B $-195\,J\,K^{-1}\,mol^{-1}$

C $-186\,J\,K^{-1}\,mol^{-1}$

D $+198\,J\,K^{-1}\,mol^{-1}$

5 At equilibrium in the same vessel of volume $1.80\,dm^3$ under altered conditions, the reaction mixture contains 0.0700 mol of $SO_3(g)$, 0.0500 mol of $SO_2(g)$ and 0.0900 mol of $O_2(g)$ at a total pressure of 623 kPa. The temperature in the equilibrium vessel is

A 307 °C

B 596 K

C 337 °C

D 642 K

6 An aqueous solution contains 4.0 g of sodium hydroxide in $250\,cm^3$ of solution.
($K_w = 1.00 \times 10^{-14}\,mol^2\,dm^{-6}$)

The pH of the solution is

A 13.0

B 13.3

C 13.6

D 13.9

7 Which one of the following best explains why the lattice enthalpy of magnesium chloride is much larger than that of lithium chloride?

A Magnesium has a greater electronegativity than lithium.

B Magnesium ions have a greater polarising power than lithium ions.

C Magnesium ions have a greater ionic radius than lithium ions.

D Magnesium ions have a greater charge than lithium ions.

8 Which one of the following would **not** reduce an acidified aqueous solution of potassium dichromate(VI)?

A CH_3COOH

B Zn

C CH_3CHO

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

9 Which one of the following would **not** react with aqueous silver nitrate to produce a precipitate that is soluble in concentrated aqueous ammonia?

A $CaBr_2$

B $[CoCl_4]^{2-}$

C $(CH_3)_4N^+I^-$

D CH_3COCl

10 In which one of the following reactions do two H^+ ions and one electron have to be added to the left-hand side in order to balance the equation?

A $CH_3CHO \rightarrow CH_3CH_2OH$

B $VO^{2+} \rightarrow V^{3+} + H_2O$

C $NO_3^- \rightarrow HNO_2 + H_2O$

D $HOCl \rightarrow \frac{1}{2}Cl_2 + H_2O$

11 Which one of the following solutions would **not** give a white precipitate when added to barium chloride solution?

A silver nitrate solution

B dilute sulphuric acid

C sodium sulphate solution

D sodium nitrate solution

12 Which equation does **not** involve the reduction of a transition metal compound?

A $Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$

B $TiO_2 + 2C + 2Cl_2 \longrightarrow TiCl_4 + 2CO$

C $Cr_2O_3 + 2Al \longrightarrow 2Cr + Al_2O_3$

D $TiCl_4 + 4Na \longrightarrow Ti + 4NaCl$

13 The minimum mass of aluminium needed to displace 1000 g of iron from an excess of iron(III) oxide is

A 2067 g

B 968 g

C 484 g

D 242 g

14 The percentage of copper in a copper(II) salt can be determined by using a thiosulphate titration. 0.305 g of a copper(II) salt was dissolved in water and added to an excess of potassium iodide solution, liberating iodine according to the following equation:

$$2Cu^{2+}(aq) + 4I^{-}(aq) \longrightarrow 2CuI(s) + I_2(aq)$$

The iodine liberated required 24.5 cm^3 of a 0.100 mol dm^{-3} solution of sodium thiosulphate:

$$2S_2O_3^{2-}(aq) + I_2(aq) \longrightarrow 2I^{-}(aq) + S_4O_6^{2-}(aq)$$

The percentage of copper, by mass, in the copper(II) salt is

A 64.2

B 51.0

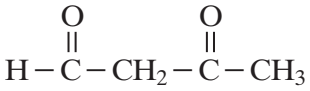
C 48.4

D 25.5

Questions 15 and 16

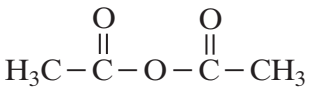
Select the most appropriate compound from the list **A** to **D**.

A



B

C



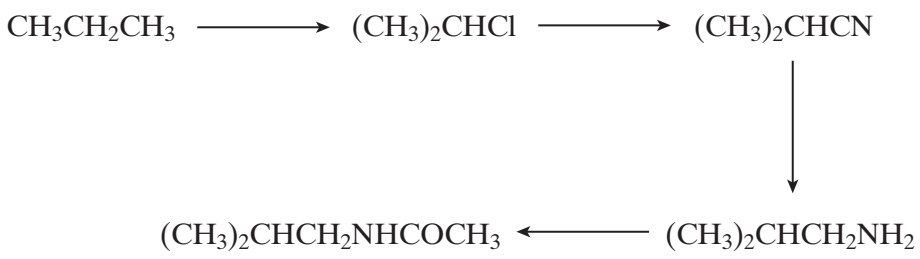
D $CH_3CH_2-O-CH_2CH_2OH$

15 Which compound is formed by the reaction of an alcohol with epoxyethane?

16 Which compound is formed by the reaction of ethane-1,2-diol with an acid?

Questions 17 and 18

Questions **17** and **18** refer to the following reaction sequence:



17 Which one of the following types of reaction is **not** involved in the above sequence?

A halogenation

B acylation

C reduction

D oxidation

18 Which one of the following types of reaction mechanism is **not** involved in the above sequence?

A free-radical substitution

B nucleophilic substitution

C elimination

D nucleophilic addition–elimination

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19 Which one of the following statements about but-2-enal, $CH_3CH{=}CHCHO$, is **not** true?

A It has stereoisomers.

B It shows a strong absorption in the infra-red at about $1700\,cm^{-1}$.

C It will turn an acidified solution of potassium dichromate(VI) green.

D It can be dehydrated by concentrated sulphuric acid.

20 Which one of the following has a major peak in its mass spectrum at $m/z = 57$?

A propanone

B 3-methylbutan-2-one

C pentan-2-one

D pentan-3-one

21 Which one of the following has a singlet peak in its proton n.m.r. spectrum?

A ethyl propanoate

B propyl methanoate

C hexan-3-one

D 2-chlorobutane

TURN OVER FOR THE NEXT QUESTION

Multiple completion questions
For each of Questions **22** 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 22 to 24

Methanol can be synthesised in the gas phase from methane and steam as shown in the reactions below.

Reaction	Equation	$\Delta H^{\ominus}$/kJ mol^{-1}	$\Delta S^{\ominus}$/J K^{-1} mol^{-1}
P	$CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$	+206	+216
Q	$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$	–91	–222
R	$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$	–41	–42
S	$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$	–49	–180

22 In which of these reactions is a high equilibrium yield favoured by both low temperature and high pressure?

(1) Reaction **P**

(2) Reaction **Q**

(3) Reaction **R**

(4) Reaction **S**

23 Which of these reactions is/are feasible at 960 K?

(1) Reaction **P**

(2) Reaction **Q**

(3) Reaction **R**

(4) Reaction **S**

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 Hazards associated with this process include

(1) methanol is a corrosive acid.

(2) methane gas can form an explosive mixture with air.

(3) carbon dioxide is a poisonous gas.

(4) hydrogen is a flammable gas.

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25 Correct statements include

(1) the carbon–carbon bond length in cyclohexane is shorter than that in benzene.

(2) the carbon–oxygen bond length in methanol is longer than that in methanal.

(3) the C–C–C bond angle in benzene is smaller than that in cyclohexane.

(4) the H–N–C bond angle in methylamine is greater than the H–O–C bond angle in methanol.

26 In which of the following species do three atoms lie in a straight line?

(1) $[Ag(NH_3)_2]^+$

(2) PF_5

(3) XeF_4

(4) $[CoCl_4]^{2-}$

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

27 Which of the following is/are colourless?

(1) iron(III) chloride solution

(2) magnesium iodide solution

(3) cobalt(II) sulphate solution

(4) silver nitrate solution

28 In which of the following reactions does the oxidation state of an element decrease by 4 units or more?

(1) $TiCl_4 + 4Na \longrightarrow Ti + 4NaCl$

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

(3) $6HI + H_2SO_4 \longrightarrow 3I_2 + S + 4H_2O$

(4) $Cr_2O_7^{2-} + 14H^+ + 6V^{2+} \longrightarrow 2Cr^{3+} + 7H_2O + 6V^{3+}$

29 Which of the following statements is/are correct?

(1) Argon is used as an inert atmosphere during the production of titanium.

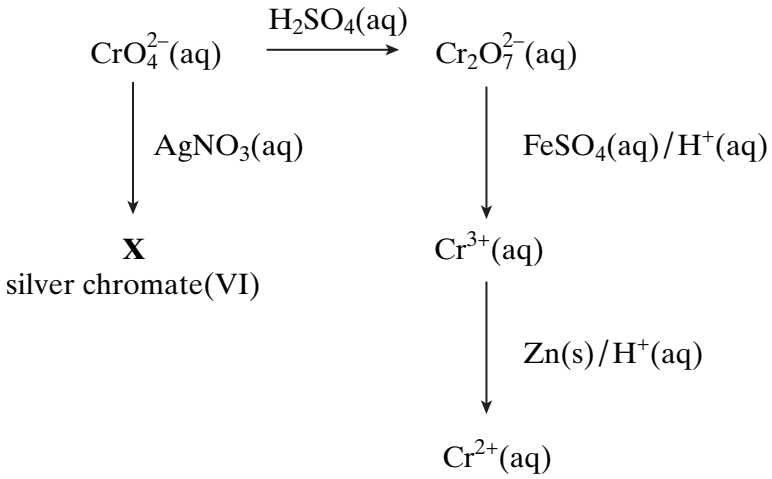
(2) One thousand moles of electrons would produce 9.0 kg of aluminium during the electrolysis of aluminium oxide.

(3) 8.4 kg of carbon monoxide would produce 11.2 kg of iron from an excess of Fe_2O_3

(4) A method used to produce titanium is to heat titanium(IV) oxide with magnesium in an inert atmosphere.

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 Consider the reaction scheme shown below:



Which of the following statements is/are true?

(1) Silver chromate(VI) has the formula Ag_2CrO_4

(2) The minimum mass of zinc required to reduce 0.100 mol of Cr^{3+} to Cr^{2+} is 6.54 g

(3) The conversion of CrO_4^{2-} into $Cr_2O_7^{2-}$ is not a redox reaction.

(4) The equation $Cr_2O_7^{2-} + 14H^+ + 9Fe^{2+} \longrightarrow 9Fe^{3+} + Cr^{3+} + 7H_2O$ correctly describes the reduction of $Cr_2O_7^{2-}$ by acidified $FeSO_4$

31 Which of the following compounds has/have one or more lone pairs of electrons on the central atom?

(1) BCl_3

(2) XeF_4

(3) PF_5

(4) PCl_3

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

32 A redox reaction occurs between which of the following?

(1) Ba^{2+} and SO_4^{2-}

(2) H^+ and CrO_4^{2-}

(3) Mg^{2+} and OH^-

(4) Fe^{3+} and I^-

33 Which of the following increase(s) down Group VII for the halogens and the halide ions?

(1) the electronegativity of the halogen

(2) the lattice dissociation energy of the sodium halide

(3) the oxidising ability of the halogen in aqueous solution

(4) the strength of the halide ion as a reducing agent in aqueous solution

34 Amphoteric hydroxides include

(1) $Al(OH)_3$

(2) $Be(OH)_2$

(3) $Cr(OH)_3$

(4) $Ca(OH)_2$

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

35 Ethane-1,2-diol could be obtained from

(1) oxidation of ethanedial by acidified potassium dichromate(VI).

(2) reaction of an excess of water with epoxyethane.

(3) acid-catalysed addition of water to ethene.

(4) reaction of bromine with ethene followed by alkaline hydrolysis.

36 Which of the following statements is/are true?

(1) Water has a singlet peak in its proton n.m.r. spectrum.

(2) Propanone has a major fragment peak at $m/z = 43$ in its mass spectrum.

(3) Water has an absorption at about $3350\,cm^{-1}$ in its infra-red spectrum.

(4) Water and ethane-1,2-diol cannot be distinguished in their infra-red spectra above $1600\,cm^{-1}$.

37 Which of the following involve(s) free radicals?

(1) reaction of chlorine with hexane to make a chlorohexane

(2) fragmentation of butanone in the mass spectrometer

(3) heating of $C_{16}H_{34}$ to make C_8H_{18} and C_2H_4

(4) production of nylon 6,6 by polymerisation

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 An excess of methane is reacted with chlorine in the presence of ultra-violet light. The principal organic product of the reaction has

(1) permanent dipole–dipole forces between molecules.

(2) van der Waals' forces between molecules.

(3) covalent bonds between atoms.

(4) hydrogen bonds between molecules.

39 Correct statements about 2-bromo-2-methylpropane include

(1) it is a secondary haloalkane.

(2) it exhibits hydrogen bonding between molecules.

(3) it has an M_r of 138.

(4) it forms 2-methylpropene when heated with ethanolic NaOH.

40 Which of the following pairs react(s) to form more than one organic product?

(1) $CH_4 + Cl_2$

(2) $CH_3CH_2Br + NH_3$

(3) $CH_3CHBrCH_3 + NaOH$

(4) $CH_3COCl + NH_3$

END OF QUESTIONS