General Certificate of Education
June 2007
Advanced Level Examination

AQA

ASSESSMENT and
QUALIFICATIONS
ALLIANCE

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

Monday 25 June 2007   9.00 am to 10.00 am

For this paper you must have:
• 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 answer book 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.

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.
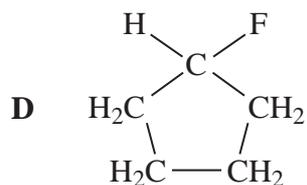
Multiple choice questions

Each of Questions **1** to **21** consists of a question or an incomplete statement followed by four suggested answers or completions. You are asked to select the most appropriate answer in each case.

Questions 1 and 2

$$P(g) \rightleftharpoons 2Q(g) \qquad \Delta H^{\ominus} \text{ is positive}$$

1 The mole fraction of Q in the above equilibrium can be increased by

  A   decreasing the temperature.

  B   adding a catalyst.

  C   increasing the volume of the reaction vessel.

  D   increasing the pressure.

2 1.0 mol of P was placed in a sealed vessel and left until the above equilibrium was established. At equilibrium, a total of 1.5 mol of gas were present. The mole fraction of Q at equilibrium was

  A   0.33

  B   0.50

  C   0.67

  D   0.75

3 The following compounds all have $M_r = 88$. Which one contains over 60% by mass of carbon **and** also exhibits hydrogen bonding?

  A $H_2N(CH_2)_4NH_2$

  B $CH_3CH_2CH_2COOH$

  C $CH_3CH_2CH_2CH_2CH_2OH$

  D

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
									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			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			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			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								

Transition elements

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
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
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
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	247.0 **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

Gas constant $R = 8.31$ J K^{-1} mol^{-1}

Table 1
Proton n.m.r chemical shift data

Type of proton	δ/ppm
RCH$_3$	0.7–1.2
R$_2$CH$_2$	1.2–1.4
R$_3$CH	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

4 $CaCl_2(s)$ has a standard lattice dissociation enthalpy of $+2237$ kJ mol^{-1}

The standard enthalpy of hydration values for $Ca^{2+}(g)$ and $Cl^-(g)$ are -1650 kJ mol^{-1} and -364 kJ mol^{-1}, respectively.

The standard enthalpy of solution of $CaCl_2(s)$ is

A -223 kJ mol^{-1}

B -141 kJ mol^{-1}

C $+141$ kJ mol^{-1}

D $+223$ kJ mol^{-1}

5 Ions of two isotopes of the transition metal nickel are shown below.

$$^{58}_{28}Ni^{2+} \qquad\qquad ^{60}_{28}Ni^{2+}$$

Which one of the following statements is correct?

A   The electron arrangement of both these Ni^{2+} ions is $1s^22s^22p^63s^23p^63d^64s^2$.

B   The $^{60}_{28}Ni^{2+}$ ion will have more protons in its nucleus than the $^{58}_{28}Ni^{2+}$ ion.

C   In the same strength magnetic field, the $^{60}_{28}Ni^{2+}$ ion will be deflected more than the $^{58}_{28}Ni^{2+}$ ion.

D   These Ni^{2+} ions have the same number of electrons but a different number of neutrons.

Questions 6 and 7

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

$$
\begin{array}{lr}
 & E^{\ominus}/\text{V} \\
Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s) & +0.34 \\
Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s) & -0.25 \\
Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s) & -0.76
\end{array}
$$

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

   A   0.59 V

   B   0.09 V

   C -0.09 V

   D -0.59 V

7 Which one of the following reactions occurs?

   A $Cu(s) + 2H^+(aq) \longrightarrow Cu^{2+}(aq) + H_2(g)$

   B $H_2(g) + Ni^{2+}(aq) \longrightarrow Ni(s) + 2H^+(aq)$

   C $Cu(s) + Ni^{2+}(aq) \longrightarrow Cu^{2+}(aq) + Ni(s)$

   D $Zn(s) + Ni^{2+}(aq) \longrightarrow Zn^{2+}(aq) + Ni(s)$

Questions 8 and 9

The following reaction is used in industry to prepare aspirin
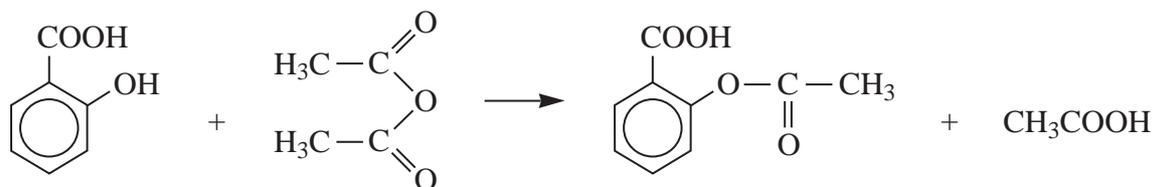
8 Which one of the following statements about ethanoic anhydride is **not** correct?

    A   It has two singlets only in its proton n.m.r. spectrum.

    B   It undergoes hydrolysis in water to give a single product with a pH value less than 7.

    C   It has a strong absorption at about $1720 \, cm^{-1}$ in its infra-red spectrum.

    D   It has a major fragment peak at $m/z = 43$ in its mass spectrum.

9 2-Hydroxybenzoic acid and aspirin are both white solids.
Which one of the following would **not** distinguish between pure samples of these two solids?

    A   comparing the laboratory-determined melting points to data-book values

    B   comparing infra-red spectra at $3250 \, cm^{-1}$

    C   comparing their effects on sodium carbonate

    D   comparing the m/z values of their molecular ions

10 Which one of the following statements is correct?

    A   There are only three isomers of dichloropropane.

    B   There are geometric isomers of 2-methylpent-2-ene.

    C   There are optical isomers of 2-aminopropanoic acid.

    D   Enantiomers can be distinguished using the fingerprint region of their infra-red spectra.

11 Aluminium chloride acts as a weak monoprotic acid in aqueous solution and has a K_a value of $1.26 \times 10^{-5} \, \text{mol dm}^{-3}$

What concentration, in mol dm^{-3}, of aluminium chloride will produce a solution with a pH value of 2.60?

    A   0.0050

    B   0.50

    C   0.53

    D   2.0

12 Which one of the following statements is correct?

    A $AlCl_3$ has a higher melting point than Al_2O_3

    B   The Al_2Cl_6 dimer contains two co-ordinate bonds.

    C $AlCl_3$ is pyramidal.

    D   The $AlCl_3$ catalyst acts as an electron pair donor in the acylation of benzene.

13 Which one of the following isomeric alkenes is formed when 3-bromo-2-methylpentane reacts with ethanolic potassium hydroxide?

    A   3-methylpent-1-ene

    B   3-methylpent-2-ene

    C   4-methylpent-2-ene

    D   2-ethylbut-1-ene

14 Sulphur dichloride oxide, $SOCl_2$, can be used to convert alcohols into chloroalkanes.

$$CH_3CH_2OH + O{=}S{\overset{Cl}{\underset{Cl}{\diagup\diagdown}}} \longrightarrow CH_3CH_2Cl + O{=}S{=}O + HCl$$
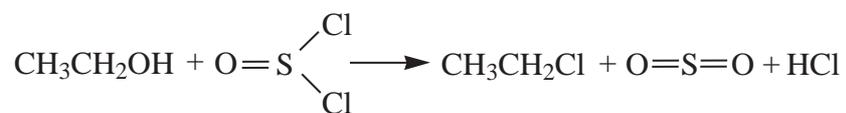
Bond	Mean bond enthalpy / $kJ\,mol^{-1}$
C–Cl	338
C–O	364
H–Cl	431
O–H	464
S–Cl	277
S=O	523
C–C	348
C–H	412

The enthalpy change, in $kJ\,mol^{-1}$, for the gas phase reaction between ethanol and sulphur dichloride oxide using the bond enthalpies given above is

A   −187

B   −90

C   +90

D   +187

Turn over for the next question

Questions 15 to 17

A car airbag contains sodium azide, NaN_3, and potassium nitrate.
Sodium azide decomposes to produce nitrogen gas and sodium metal.

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$
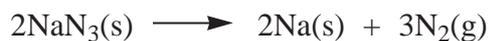
The sodium produced reacts immediately with the potassium nitrate producing more nitrogen.

$$10Na(s) + 2KNO_3(s) \longrightarrow N_2(g) + 5Na_2O(s) + K_2O(s)$$

15   The total number of moles of nitrogen produced by 1.0 mol of sodium azide in this sequence is

   A   1.0

   B   1.5

   C   1.6

   D   4.0

16   The number of moles of nitrogen needed to produce a pressure of 200 kPa in an airbag of volume $0.060 \, m^3$ at a temperature of 27 °C is

   A   0.21

   B   4.8

   C   54

   D   4800

17   An element which undergoes oxidation in the above reactions is

   A   sodium in NaN_3

   B   potassium in KNO_3

   C   oxygen in KNO_3

   D   nitrogen in NaN_3

Questions 18 and 19

Use the curves below, obtained using equal volumes of solutions of two monoprotic acids **HX** and **HY**, to answer Questions **18** and **19**.

Volume of $0.10\,\text{mol dm}^{-3}$ NaOH(aq) added$/\text{cm}^3$
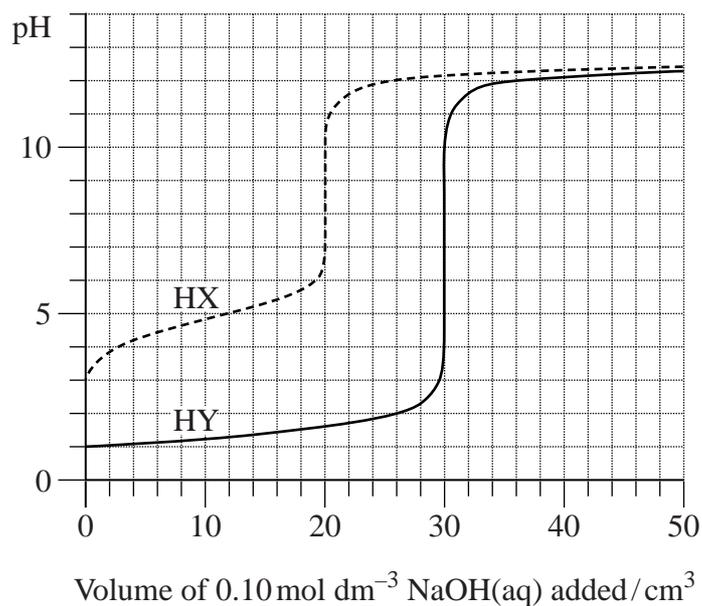
18 Which one of the following statements about a solution of HX is correct?

A   It is less concentrated and contains a weaker acid than the solution of HY.

B   It is more concentrated and contains a stronger acid than the solution of HY.

C   It is more concentrated and contains a weaker acid than the solution of HY.

D   It is less concentrated and contains a stronger acid than the solution of HY.

19 The value, in mol dm^{-3}, of K_a for the acid HX is

A 1.3×10^{-2}

B 1.0×10^{-3}

C 1.3×10^{-5}

D 8.3×10^{-6}

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

    A   It has a positive enthalpy of combustion.

    B   It is formed during the incomplete combustion of alkanes.

    C   It is oxidised to carbon dioxide when heated strongly with iron(III) oxide.

    D   Compared with an oxygen molecule, it can form a stronger co-ordinate bond with iron(II) in haemoglobin.

21 Locate the element tungsten (W) in the Periodic Table.

Which one of the following explains why tungsten is a poor catalyst?

    A   It exists only in one oxidation state.

    B   It has an incomplete d sub-level.

    C   It has no active sites on its surface.

    D   Reacting molecules are adsorbed strongly onto its surface.

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** 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

22 The extraction of titanium from titanium(IV) oxide involves two reactions represented by the following equations

$$TiO_2 + 2C + 2Cl_2 \rightarrow TiCl_4 + 2CO$$

$$TiCl_4 + 4Na \rightarrow Ti + 4NaCl$$
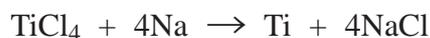
Correct statements about the extraction include

1 149.6 kg of chlorine are needed to make 200.0 kg of titanium(IV) chloride ($M_r = 189.9$).

2 both of the above equations represent redox reactions.

3 titanium is expensive because the extraction involves a batch process.

4 the second reaction is carried out in an atmosphere of nitrogen to prevent oxidation of the product.

23 Anhydrous compounds of Period 3 elements that react with water to give solutions with a pH value less than 5 include

1 ionic chlorides.

2 covalent chlorides.

3 ionic oxides.

4 covalent oxides.

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 Correct statements about concentrated sulphuric acid include

1 it reacts with butan-2-ol to form but-1-ene.

2 it is reduced to hydrogen sulphide by solid sodium iodide.

3 it can protonate concentrated nitric acid.

4 it reacts with sodium chloride to form chlorine gas.

Questions 25 to 27 are about the synthesis and reactions of compounds **M** and **N** shown below.

$$CH_3COOH \xrightarrow{\text{Step (i)}} ClCH_2COOH \xrightarrow{\text{Step (ii)}} NCCH_2COOH \xrightarrow{\text{Step (iii)}} HOOCCH_2COOH$$

$$\textbf{J} \qquad \qquad \textbf{K} \qquad \qquad \textbf{L} \qquad \qquad \textbf{M}$$

Step (iv)

$$H_2NCH_2CH_2COOH$$

$$\textbf{N}$$
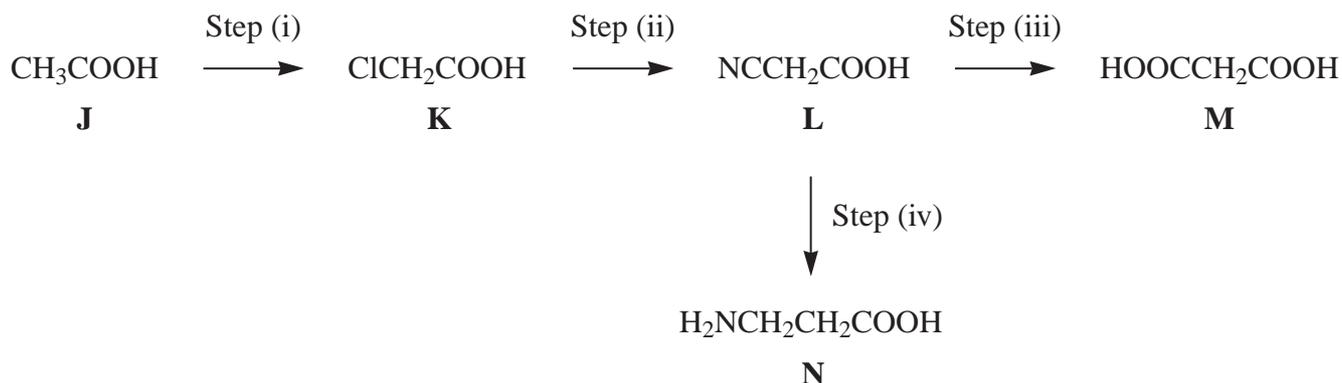
25 Correct statements about the reaction scheme include

1 Step (i) could be achieved using chlorine in the presence of ultra-violet light.

2 Step (ii) could be achieved using potassium cyanide.

3 Step (iv) could be achieved using hydrogen in the presence of nickel.

4 **K** could be converted directly into **N** using ammonia.

26 Correct statements about **M** include

1 it can form a condensation polymer with 1,6-diaminohexane.

2 complete reaction of $0.0100 \, \text{mol}$ of **M** requires $10.0 \, \text{cm}^3$ of $1.00 \, \text{mol} \, \text{dm}^{-3}$ NaOH(aq)

3 it can act as a bidentate ligand.

4 its systematic name is ethanedioic acid.

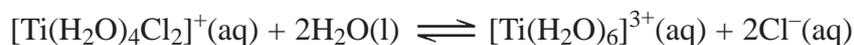| Directions summarised			
A	**B**	**C**	**D**
1, **2** and **3** only correct	**1** and **3** only correct	**2** and **4** only correct	**4** only correct

27 Correct statements about **N** include

1 it exists as the ion $HOOCCH_2CH_2NH_3^+$ in a solution at pH 14.

2 it reacts with methanol to form a tetraalkylammonium salt.

3 it reacts with ethanoyl chloride to form an ester.

4 it undergoes self-polymerisation.

28 Results which support the identification of an unknown compound as propyl methanoate include

1 a strong absorption in its infra-red spectrum at $1740\,cm^{-1}$.

2 a singlet peak integrating for three protons in its proton n.m.r. spectrum.

3 the compound contains 54.54% of carbon by mass.

4 it effervesces with sodium hydrogencarbonate.

**29** Consider the species in the following equation.

$$[Ti(H_2O)_4Cl_2]^+(aq) + 2H_2O(l) \rightleftharpoons [Ti(H_2O)_6]^{3+}(aq) + 2Cl^-(aq)$$

Correct statements include

1 water acts as a Lewis base.

2 the complex ions are both octahedral.

3 the $[Ti(H_2O)_6]^{3+}$ ion can act as a Brønsted–Lowry acid.

4 the electron arrangement of the Ti^{3+} ion is $[Ar]4s^1$

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

30 Optical isomerism is shown by

1

$$C_6H_5 - \overset{\displaystyle H}{\underset{\displaystyle CH_3}{N^+}} - CH_2CH_3$$

2

3

4
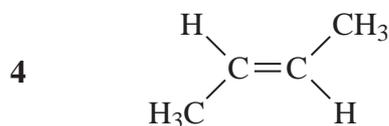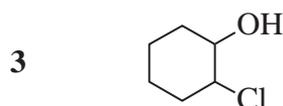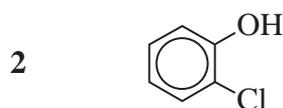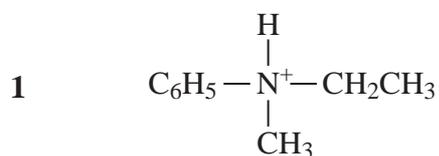
31 Species with four or more atoms in the same plane include

1 cisplatin.

2 but-2-ene.

3 benzene.

4 an ammonium ion.

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 For the reaction represented by the equation shown below,

$$2H_2(g) + 2NO(g) \longrightarrow 2H_2O(g) + N_2(g)$$
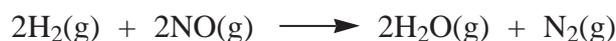
the rate equation is
$$\text{rate} = k[H_2][NO]^2$$

Assuming that each 10 K rise in temperature doubles the rate, which of the following will increase the rate by a factor of four?

1 a 20 K temperature increase, keeping $[H_2]$ and $[NO]$ constant.

2 a 10 K temperature increase with $2 \times [H_2]$, keeping $[NO]$ constant.

3 no temperature change but with $4 \times [H_2]$, keeping $[NO]$ constant.

4 a 10 K temperature increase with $2 \times [NO]$, keeping $[H_2]$ constant.

33 Which of the following increase(s) down Group VII?

1 the electronegativity of the halogen

2 the lattice dissociation enthalpy of the sodium halide

3 the oxidising ability of the halogen

4 the strength of the halide ion as a reducing agent

34 Correct statements include

1 the base strength increases from methylamine to ammonia to phenylamine.

2 the melting point increases from pentan-3-one to pentan-2-ol to 2-aminopropanoic acid.

3 the carbon to carbon bond enthalpy increases from ethene to benzene to ethane.

4 the pH of a $1.0 \, \text{mol} \, \text{dm}^{-3}$ solution increases from sulphuric acid to hydrochloric acid to ethanoic acid.

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 Solids that have a macromolecular structure include

    1   MgO

    2 $C_{17}H_{35}COONa$

    3 P_4O_{10}

    4   Si

36 Equations that represent redox reactions include

    1 $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

    2 $[V(H_2O)_4Cl_2]^+ + 2H_2O \rightarrow [V(H_2O)_6]^{3+} + 2Cl^-$

    3 $Mg + S \rightarrow MgS$

    4 $CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$

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

Questions 37 and 38

Use the following reaction scheme to answer questions **37** and **38**.

$$\textbf{P} \qquad\qquad \textbf{Q} \qquad\qquad \textbf{S}$$
$$CH_3CH=CHCH_3 \longleftarrow CH_3CH(OH)CH_2CH_3 \longrightarrow CH_3COCH_2CH_3$$

$$\downarrow$$

$$CH_3COOCH(CH_3)CH_2CH_3$$
$$\textbf{R}$$
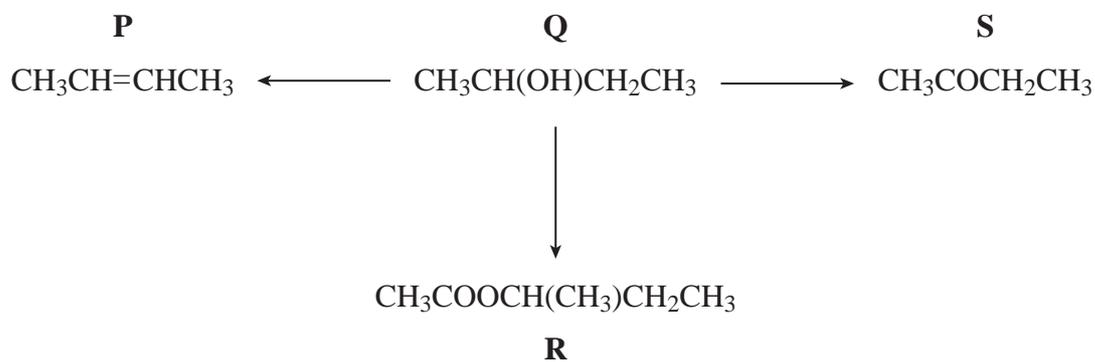
37 Compounds that have stereoisomers include

1 P

2 Q

3 R

4 S

38 Types of reaction in the scheme include

1 dehydration.

2 hydrogenation.

3 esterification.

4 alkylation.

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 Conversions that require four moles of hydrogen gas per mole of starting material include

1

2

$$N \equiv C(CH_2)_4 C \equiv N \longrightarrow H_2N(CH_2)_6NH_2$$

3

4
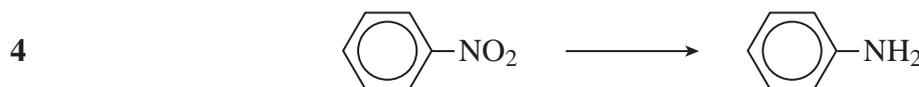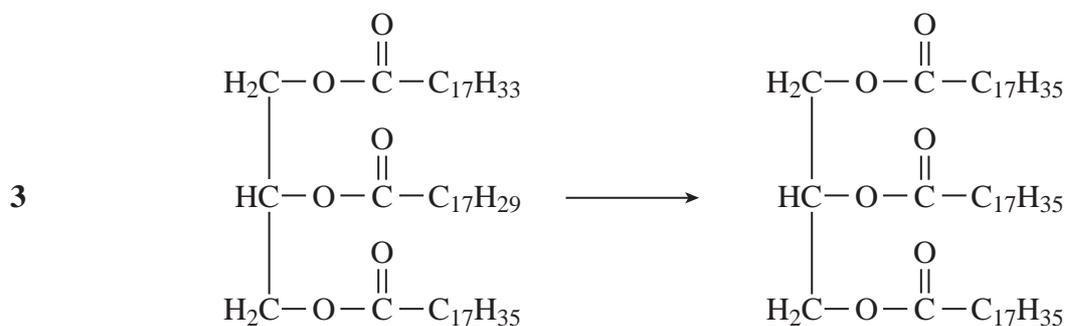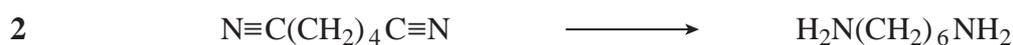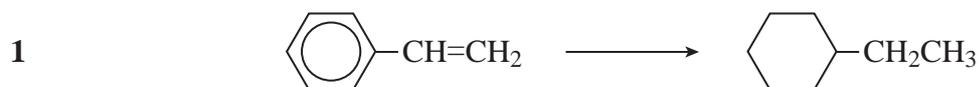
40 Correct statements about chloroethanoic acid include

1 it gives an immediate white precipitate with silver nitrate solution.

2 it gives a silver mirror with Tollens' reagent.

3 it gives colourless fumes on addition of water.

4 a mixture of acidified potassium dichromate(VI) and the acid remains orange on warming.

END OF QUESTIONS