| Surname | | Other Names | |
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| Centre Number | | Candidate Number | |
| Candidate Signature | | | |

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General Certificate of Education
January 2004
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

# CHEMISTRY CHM2
# Unit 2 Foundation Physical and Inorganic Chemistry

Friday 9 January 2004 Morning Session

**In addition to this paper you will require:**
a calculator.

Time allowed: 1 hour

**Instructions**

- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions in **Section A** and **Section B** in the spaces provided. All working must be shown.
- Do all rough work in this book. Cross through any work you do not want marked.
- 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 60.
- Mark allocations are shown in brackets.
- This paper carries 30 per cent of the total marks for AS. For Advanced Level this paper carries 15 per cent of the total marks.
- You are expected to use a calculator where appropriate.
- The following data may be required.
  Gas constant $R = 8.31\,J\,K^{-1}\,mol^{-1}$
- Your answers to the question in **Section B** should be written in continuous prose, where appropriate. You will be assessed on your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist vocabulary, where appropriate.

**Advice**

- You are advised to spend about 45 minutes on **Section A** and about 15 minutes on **Section B**.

| For Examiner's Use | | | |
|---|---|---|---|
| Number | Mark | Number | Mark |
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| TOTAL | | | |
| Examiner's Initials | | | |

## SECTION A

Answer **all** questions in the spaces provided.

**1** Hydrogen is produced on an industrial scale from methane as shown by the equation below.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H^{\ominus} = +205\,kJ\,mol^{-1}$$

(a) State Le Chatelier's principle.

.....

.....

*(1 mark)*

(b) The following changes are made to this reaction at equilibrium. In each case, predict what would happen to the yield of hydrogen from a given amount of methane. Use Le Chatelier's principle to explain your answer.

(i) The overall pressure is increased.

*Effect on yield of hydrogen* .....

*Explanation* .....

.....

.....

(ii) The concentration of steam in the reaction mixture is increased.

*Effect on yield of hydrogen* .....

*Explanation* .....

.....

.....

*(6 marks)*

(c) At equilibrium, a high yield of hydrogen is favoured by high temperature. In a typical industrial process, the operating temperature is usually less than 1200 K. Suggest two reasons why temperatures higher than this are not used.

*Reason 1* .....

*Reason 2* .....

*(2 marks)*

9

# 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

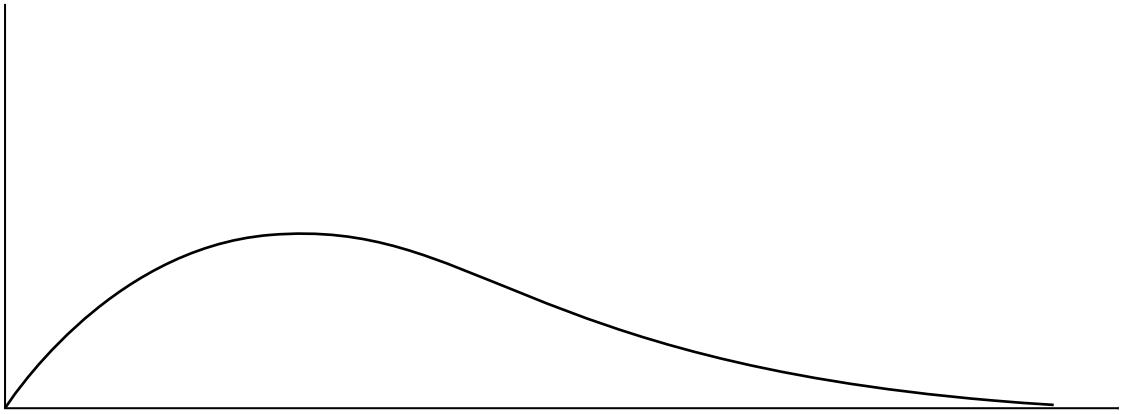
**Table 1**
Proton n.m.r chemical shift data

| **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 |

**2** The diagram below represents a Maxwell–Boltzmann distribution curve for the particles in a sample of a gas at a given temperature. The questions below refer to this sample of particles.



(a) Label the axes on the diagram. *(2 marks)*

(b) On the diagram draw a curve to show the distribution for this sample at a **lower** temperature. *(2 marks)*

(c) In order for two particles to react they must collide. Explain why most collisions do not result in a reaction.

.....

*(1 mark)*

(d) State one way in which the collision frequency between particles in a gas can be increased without changing the temperature.

.....

*(1 mark)*

(e) Suggest why a small increase in temperature can lead to a large increase in the reaction rate between colliding particles.

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*(2 marks)*

(f) Explain in general terms how a catalyst works.

.....

.....

.....

*(2 marks)*

10

**3** (a) Identify the halogen that is the strongest oxidising agent.

.....

*(1 mark)*

(b) Give the formula of the halide ion that is the strongest reducing agent.

.....

*(1 mark)*

(c) Describe what you would observe in each case when aqueous silver nitrate is added separately to dilute aqueous sodium fluoride and to dilute aqueous sodium iodide. Write an equation, including state symbols, for the reaction between aqueous sodium iodide and aqueous silver nitrate.

*Observation with NaF(aq)* .....

*Observation with NaI(aq)* .....

*Equation* .....

*(3 marks)*

(d) Describe what you would observe when concentrated sulphuric acid is added to solid sodium chloride. Write an equation for the reaction that occurs.

*Observation* .....

*Equation* .....

*(2 marks)*

(e) Describe two observations that you would make when concentrated sulphuric acid is added to solid sodium iodide. Write an equation for a reaction that occurs in which iodide ions are oxidised by the sulphuric acid.

*Observation 1* .....

*Observation 2* .....

*Equation* .....

.....

.....

*(4 marks)*

(f) Describe the colour change that you would observe when an aqueous solution of iodine, to which starch solution has been added, reacts with an excess of $Na_2S_2O_3$. Write an equation for the reaction that occurs between iodine and $Na_2S_2O_3$.

*Observation* .....

*Equation* .....

*(3 marks)*

**4** The extraction of metals involves redox reactions.

(a) In terms of electrons, state what happens in a redox reaction.

.....

.....

*(1 mark)*

(b) Titanium is extracted from titanium(IV) oxide in a two-step batch process.

(i) Write an equation for the first step in this process in which titanium(IV) oxide is converted into titanium(IV) chloride. Identify the oxidising and reducing agents in this step.

*Equation* .....

*Oxidising agent* .....

*Reducing agent* .....

(ii) Write an equation for the second step in this process in which titanium(IV) chloride is converted into titanium metal. State two important conditions for this step and in each case explain why the conditions are necessary.

*Equation* .....

*Condition 1* .....

*Explanation* .....

.....

*Condition 2* .....

*Explanation* .....

.....

*(10 marks)*

(c) Give the major reason why recycling aluminium is economically viable.

.....

*(1 mark)*

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## SECTION B

Answer the question below in the space provided on pages 8 to 10 of this booklet.

**5** (a) Define the term *standard enthalpy of formation*.

*(3 marks)*

(b) State Hess's Law and use it, together with the data given in the table below, to calculate the standard enthalpy change for the following reaction.

$$MgO(s) + 2HCl(g) \rightarrow MgCl_2(s) + H_2O(l)$$

| | MgO(s) | HCl(g) | $MgCl_2$(s) | $H_2O$(l) |
|---|---|---|---|---|
| $\Delta H_f^{\ominus}$/kJ mol$^{-1}$ | −602 | −92 | −642 | −286 |

*(4 marks)*

(c) In an experiment, an excess of solid magnesium oxide was added to 50 cm$^3$ of 3.0 mol dm$^{-3}$ hydrochloric acid. The initial temperature of the solution was 21 °C. After reaction, the temperature had risen to 53 °C. (The specific heat capacity of water is 4.2 J K$^{-1}$ g$^{-1}$)

Use this information to calculate the enthalpy change for the reaction of one mole of magnesium oxide with hydrochloric acid. For your calculation you should assume that all the heat from the reaction is used to raise the temperature of 50 g of water.

*(8 marks)*

**END OF QUESTIONS**

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