Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
June 2004
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

CHEMISTRY **CHM2**
Unit 2 Foundation Physical and Inorganic Chemistry

Thursday 10 June 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 $R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
- 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
1			
2			
3			
4			
5			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

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SECTION A

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

1 (a) The table below contains some mean bond enthalpy data.

Bond	H–O	O–O	O=O
Mean bond enthalpy/kJ mol^{-1}	463	146	496

The bonding in hydrogen peroxide, H_2O_2, can be represented by H–O–O–H. Use these data to calculate the enthalpy change for the following reaction.

$$H_2O_2(g) \rightarrow H_2O(g) + \tfrac{1}{2}O_2(g)$$

....

....

....

....

(3 marks)

(b) The standard enthalpy of formation, $\Delta H_f^{\ominus}$, for methane, is -74.9 kJ mol^{-1}. Write an equation, including state symbols, for the reaction to which this enthalpy change applies.

....

(2 marks)

(c) The enthalpy changes for the formation of atomic hydrogen and atomic carbon from their respective elements in their standard states are as follows.

$$\tfrac{1}{2}H_2(g) \rightarrow H(g) \quad \Delta H^{\ominus} = +218\text{ kJ mol}^{-1}$$

$$C(s) \rightarrow C(g) \quad \Delta H^{\ominus} = +715\text{ kJ mol}^{-1}$$

(i) By reference to its structure, suggest why a large amount of heat energy is required to produce free carbon atoms from solid carbon.

....

....

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
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 †															

* **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	247.1 **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

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

(ii) Parts (b) and (c) give enthalpy data for the formation of CH_4(g), H(g) and C(g). Use these data and Hess's Law to calculate the value of the enthalpy change for the following reaction.

$$CH_4(g) \rightarrow C(g) + 4H(g)$$

....

....

....

....

....

(iii) Use your answer from part (c)(ii) to calculate a value for the mean bond enthalpy of a C–H bond in methane.

....

(5 marks)

10

TURN OVER FOR THE NEXT QUESTION

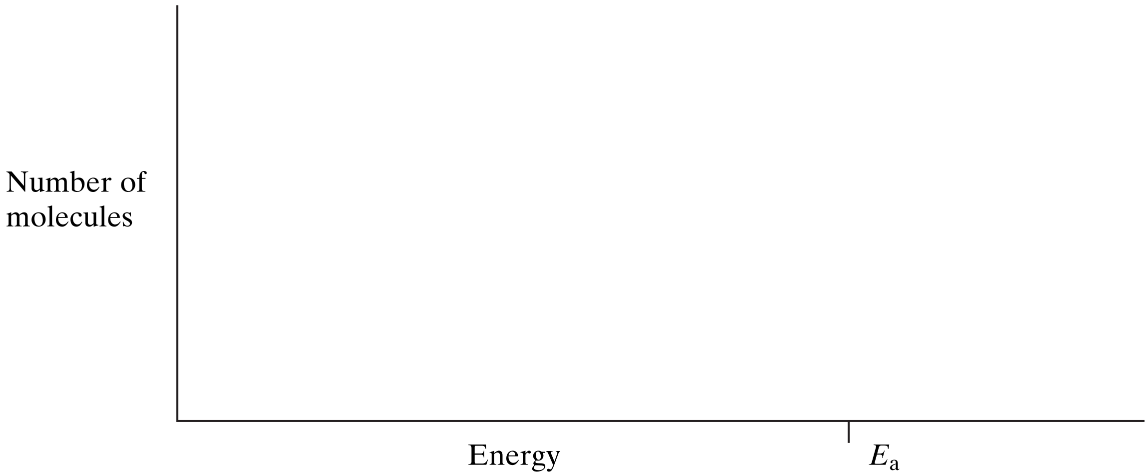
Turn over ▶

NO QUESTIONS APPEAR ON THIS PAGE

2 Gas **G** decomposes as shown in the equation below.

$$G(g) \rightarrow X(g) + Y(g)$$

(a) Draw, on the axes below, a Maxwell–Boltzmann distribution curve for a sample of **G** in which only a small proportion of molecules has energy greater than the activation energy, E_a.



(3 marks)

(b) Define the term *activation energy*.

....

....

(2 marks)

(c) At any time, most of the molecules of **G** have energy less than the activation energy. Suggest why, at a constant temperature, most of **G** eventually decomposes.

....

....

(2 marks)

(d) State the effect, if any, of adding a catalyst on the time required for **G** to decompose, compared with a similar sample without a catalyst. Explain in general terms how the catalyst has this effect.

Time for decomposition ....

Explanation ....

....

(3 marks)

10

Turn over ▶

3 Methanol can be formed on an industrial scale from carbon dioxide and hydrogen by a reversible reaction as shown below.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

The reaction can be carried out in the presence of a chromium-based catalyst at a temperature of 700 K and a pressure of 30 MPa. Under these conditions, equilibrium is reached when 2% of the carbon dioxide has been converted.

(a) How does the rate of the forward reaction compare with that of the backward reaction when 2% of the carbon dioxide has been converted?

....

(1 mark)

(b) (i) If the pressure was reduced but the temperature was kept the same, deduce what would happen to the equilibrium yield of methanol. Explain your answer.

Yield ....

Explanation ....

....

....

(ii) Give two reasons why, in general, industry prefers to operate processes at pressures lower than 30 MPa.

Reason 1 ....

Reason 2 ....

(5 marks)

(c) If the chromium-based catalyst was replaced with a more efficient catalyst but other conditions were kept the same, deduce what would happen to the equilibrium yield of methanol. Explain your answer.

Yield ....

Explanation ....

....

(2 marks)

(d) In the presence of a very efficient copper-based catalyst, this industrial process can be operated at a lower temperature of 500 K and a pressure of 30 MPa. Under these conditions, at equilibrium, more of the carbon dioxide is converted into methanol.

Use this information to deduce the sign of the enthalpy change for the reaction. Explain your deduction.

Sign of enthalpy change ....

Explanation ....

....

....

(3 marks)

(e) In the processes above, the equilibrium yield of methanol is low. Suggest what is done with the unreacted carbon dioxide and hydrogen.

....

(1 mark)

12

TURN OVER FOR THE NEXT QUESTION

4 Chlorine and bromine are both oxidising agents.

(a) Define an *oxidising agent* in terms of electrons.

....

(1 mark)

(b) In aqueous solution, bromine oxidises sulphur dioxide, SO_2, to sulphate ions, SO_4^{2-}

(i) Deduce the oxidation state of sulphur in SO_2 and in SO_4^{2-}

SO_2 ....

SO_4^{2-} ....

(ii) Deduce a half-equation for the reduction of bromine in aqueous solution.

....

(iii) Deduce a half-equation for the oxidation of SO_2 in aqueous solution forming SO_4^{2-} and H^+ ions.

....

(iv) Use these two half-equations to construct an overall equation for the reaction between aqueous bromine and sulphur dioxide.

....

(5 marks)

(c) Write an equation for the reaction of chlorine with water. Below each of the chlorine-containing products in your equation, write the oxidation state of chlorine in that product.

....

....

(3 marks)

(d) Give a reason why chlorine is not formed when solid potassium chloride reacts with concentrated sulphuric acid.

....

(1 mark)

(e) Write an equation for the reaction between solid potassium chloride and concentrated sulphuric acid.

....

(1 mark)

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(f) Solid potassium bromide undergoes a redox reaction with concentrated sulphuric acid.

(i) Give the oxidation product formed from potassium bromide.

....

(ii) Give the reduction product formed from sulphuric acid.

....

(2 marks)

13

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

SECTION B

Answer the question below in the space provided on pages 12 to 16 of this booklet.

5 (a) Explain, with the aid of equations, how the silicon-containing impurity in iron ore is removed in the Blast Furnace.
Identify the major impurity in the molten iron from the Blast Furnace and explain with the aid of an equation how this element is removed from iron on an industrial scale.
(8 marks)

(b) Describe how aluminium is manufactured from purified bauxite. Illustrate your answer by writing equations.
State the major economic benefit arising from the recycling of aluminium. What is the major problem associated with this recycling process? *(7 marks)*

END OF QUESTIONS

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