Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
June 2006
Advanced Subsidiary Examination

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

Wednesday 7 June 2006 9.00 am to 10.00 am

For this paper you must have
- 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.
- Answer **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.
- The marks for part questions are shown in brackets.
- You are expected to use a calculator where appropriate.
- Write your answers to the question in **Section B** 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			

SECTION A

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

1 (a) Define the term *standard enthalpy of formation*, $\Delta H_f^\ominus$

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(3 marks)

(b) Use the data in the table to calculate the standard enthalpy of formation of liquid methylbenzene, C_7H_8

Substance	C(s)	H_2(g)	C_7H_8(l)
Standard enthalpy of combustion, $\Delta H_c^\ominus$/ kJ mol^{-1}	–394	–286	–3909

$$7C(s) + 4H_2(g) \longrightarrow C_7H_8(l)$$

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....

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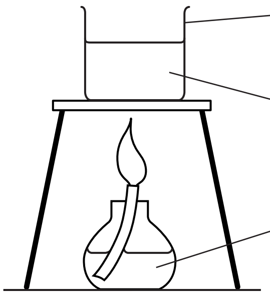
(3 marks)

(c) An experiment was carried out to determine a value for the enthalpy of combustion of liquid methylbenzene using the apparatus shown in the diagram.



Burning 2.5 g of methylbenzene caused the temperature of 250 g of water to rise by 60 °C. Use this information to calculate a value for the enthalpy of combustion of methylbenzene, C_7H_8
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1}. Ignore the heat capacity of the container.)

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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
.0 **H** Hydrogen																	4.0 **He** Helium 2
.9 **Li** Lithium	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
3.0 **Na** Sodium 1	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
9.1 **K** otassium 9	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
5.5 **Rb** Rubidium 7	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
32.9 **Cs** Caesium 5	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
23.0 **Fr** Francium 7	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

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

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

(d) A 25.0 cm^3 sample of 2.00 mol dm^{-3} hydrochloric acid was mixed with 50.0 cm^3 of a 1.00 mol dm^{-3} solution of sodium hydroxide. Both solutions were initially at 18.0 °C.

After mixing, the temperature of the final solution was 26.5 °C.

Use this information to calculate a value for the standard enthalpy change for the following reaction.

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

In your calculation, assume that the density of the final solution is 1.00 g cm^{-3} and that its specific heat capacity is the same as that of water. (Ignore the heat capacity of the container.)

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(4 marks)

(e) Give **one** reason why your answer to part (d) has a much smaller experimental error than your answer to part (c).

....

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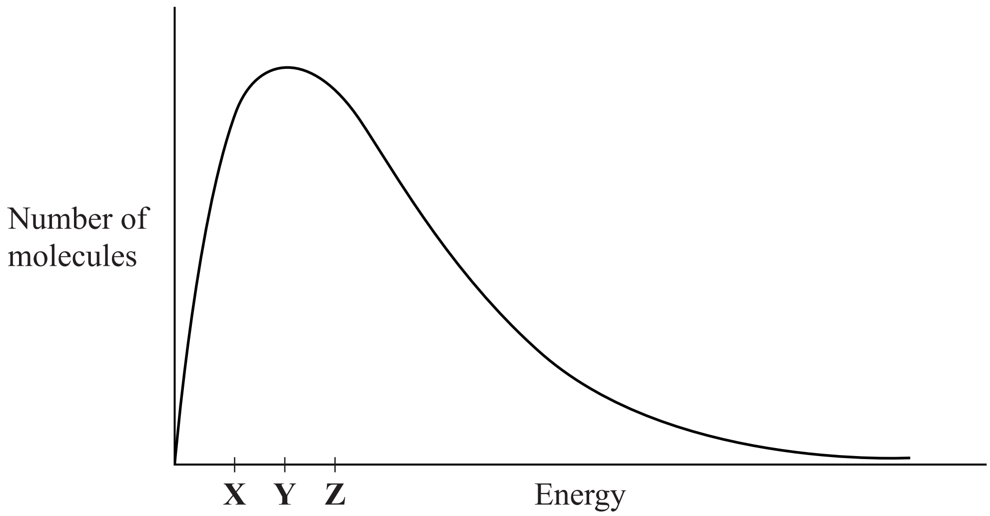
(1 mark)

15

Turn over for the next question

2 The diagram below shows the Maxwell–Boltzmann distribution of molecular energies in a sample of a gas.



(a) (i) State which one of **X**, **Y** or **Z** best represents the mean energy of the molecules.

....

(ii) Explain the process that causes some molecules in this sample to have very low energies.

....

....

(3 marks)

(b) On the diagram above, sketch a curve to show the distribution of molecular energies in the same sample of gas at a higher temperature. *(2 marks)*

(c) (i) Explain why, even in a fast reaction, a very small percentage of collisions leads to a reaction.

....

....

(ii) Other than by changing the temperature, state how the proportion of successful collisions between molecules can be increased. Explain why this method causes an increase in the proportion of successful collisions.

Method for increasing the proportion of successful collisions ....

....

Explanation ....

....

(4 marks)

3 In the Haber Process for the manufacture of ammonia, nitrogen and hydrogen react as shown in the equation.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H^{\ominus} = -92\,kJ\,mol^{-1}$$

The table shows the percentage yield of ammonia, under different conditions of pressure and temperature, when the reaction has reached dynamic equilibrium.

Temperature / K	600	800	1000
% yield of ammonia at 10 MPa	50	10	2
% yield of ammonia at 20 MPa	60	16	4
% yield of ammonia at 50 MPa	75	25	7

(a) Explain the meaning of the term *dynamic equilibrium*.

....

....

(2 marks)

(b) Use Le Chatelier's principle to explain why, at a given temperature, the percentage yield of ammonia increases with an increase in overall pressure.

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(3 marks)

(c) Give a reason why a high pressure of 50 MPa is not normally used in the Haber Process.

....

(1 mark)

(d) Many industrial ammonia plants operate at a compromise temperature of about 800 K.

(i) State and explain, by using Le Chatelier's principle, one advantage, other than cost, of using a temperature lower than 800 K.

Advantage ....

Explanation ....

....

(ii) State the major advantage of using a temperature higher than 800 K.

....

(iii) Hence explain why 800 K is referred to as a *compromise temperature*.

....

(5 marks)

11

4 Iron is extracted from iron(III) oxide in a continuous process, whereas titanium is extracted from titanium(IV) oxide in a batch process.

(a) Suggest why a high-temperature batch process is less energy-efficient than a high-temperature continuous process.

....

....

(2 marks)

(b) Write an overall equation for the reduction of iron(III) oxide in the Blast Furnace.

....

(2 marks)

(c) Write two equations to show how titanium is extracted from titanium(IV) oxide in a two-stage process.

Equation for stage 1 ....

Equation for stage 2 ....

(4 marks)

(d) Give the major reason, other than its production in a batch process, why titanium is a more expensive metal than aluminium.

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(1 mark)

(e) Give the major reason why aluminium is more expensive to extract than iron.

....

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(1 mark)

10

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SECTION B

Answer the question in the space provided on pages 9 to 12 of this booklet.

5 (a) Explain, by referring to electrons, the meaning of the terms *reduction* and *reducing agent*. *(2 marks)*

(b) Iodide ions can reduce sulphuric acid to three different products.

(i) Name the **three** reduction products and give the oxidation state of sulphur in each of these products.

(ii) Describe how observations of the reaction between solid potassium iodide and concentrated sulphuric acid can be used to indicate the presence of any **two** of these reduction products.

(iii) Write half-equations to show how two of these products are formed by reduction of sulphuric acid. *(10 marks)*

(c) Write an equation for the reaction that occurs when chlorine is added to cold water. State whether or not the water is oxidised and explain your answer. *(3 marks)*

END OF QUESTIONS

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