Surname		Other Names	
Centre Number			Candidate Number									
Candidate Signature												

For Examiner's Use

General Certificate of Education
June 2009
Advanced Subsidiary Examination

CHEMISTRY **CHM1**
Unit 1 Atomic Structure, Bonding and Periodicity

Wednesday 3 June 2009 9.00 am to 10.00 am

For this paper you must have
- a calculator.

Time allowed: 1 hour

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- Answer the questions in **Section A** and **Section B** in the spaces provided. Answers written in margins or on blank pages will not be marked.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be 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 questions are shown in brackets.
- You are expected to use a calculator where appropriate.
- Write your answers to the questions 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			
Question	Mark	Question	Mark
1			
2			
3			
4			
5			
6			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

SECTION A

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

1 (a) (i) Complete the electron arrangement of the selenium (Se) atom.

$1s^2$ .....

(1 mark)

1 (a) (ii) State the block in the Periodic Table to which selenium belongs. Explain your answer.

Block .....

Explanation .....

.....

(2 marks)

1 (b) (i) State what is meant by the term *mass number* of an atom.

.....

(1 mark)

1 (b) (ii) Deduce the symbol, including the mass number, of an atom that has four fewer protons and four fewer neutrons than an atom of ^{76}Se

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(2 marks)

1 (c) (i) Explain how atoms are ionised in a mass spectrometer.

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(2 marks)

1 (c) (ii) State how the ions are detected when they collide with the detector in a mass spectrometer.

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(1 mark)

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** Radius 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

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_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

1 (d) The table below gives the relative abundance of each isotope in a mass spectrum of a sample of selenium.

m/z	76	78	80	82
Relative abundance (%)	11.2	23.8	49.8	15.2

Use these data to calculate the relative atomic mass of this sample of selenium. Give your answer to **one** decimal place.

.....

.....

.....

(2 marks)

11

Turn over for the next question

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

2 (a) Balance the equation, given below, for the reaction in which H_2Se is formed from Al_2Se_3

$$Al_2Se_3 + \ldots\ldots H_2O \longrightarrow \ldots\ldots Al(OH)_3 + \ldots\ldots H_2Se$$

(1 mark)

2 (b) (i) Draw the shape of an H_2Se molecule and the shape of an NH_3 molecule. In each case show any lone pairs of electrons.

H_2Se NH_3

(2 marks)

2 (b) (ii) Name the shape produced by the arrangement of **atoms** in an H_2Se molecule.

.....

(1 mark)

2 (b) (iii) State the bond angle in an NH_3 molecule and explain why the bond angle in an H_2Se molecule is smaller than this.

Bond angle in NH_3 .....

Explanation for smaller bond angle in H_2Se .....

.....

.....

(3 marks)

2 (c) Describe how the covalent bonds are formed in an H_2Se molecule.

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.....

.....

(2 marks)

9

3 When aqueous aluminium sulphate reacts with aqueous barium chloride, a white precipitate of barium sulphate is formed. An equation for this reaction is shown below.

$$Al_2(SO_4)_3(aq) + 3BaCl_2(aq) \longrightarrow 3BaSO_4(s) + 2AlCl_3(aq)$$

Hydrated aluminium sulphate has the formula $Al_2(SO_4)_3.xH_2O$, where xH_2O represents the water of crystallisation.

A sample of hydrated aluminium sulphate of mass 20.0 g was dissolved in water and the solution made up to 250 cm^3.

An excess of aqueous barium chloride was added to a 25.0 cm^3 portion of this aluminium sulphate solution.

All the sulphate ions reacted to form a precipitate of barium sulphate.

When filtered, washed and dried, the mass of the barium sulphate precipitate was 2.10 g.

3 (a) (i) Calculate the number of moles of barium sulphate (M_r = 233.4) in the precipitate.

.....

.....

(1 mark)

3 (a) (ii) Calculate the number of moles of aluminium sulphate in the 25.0 cm^3 portion of the solution and in the original 20.0 g sample.

Moles in 25.0 cm^3 .....

.....

Moles in original sample .....

.....

(2 marks)

3 (b) Calculate the M_r of this sample of hydrated aluminium sulphate and hence deduce the value of x in $Al_2(SO_4)_3.xH_2O$
(If you have been unable to obtain an answer for the number of moles of aluminium sulphate in the original sample, in part (a) (ii), you may assume that the answer is 3.17×10^{-2} mol. This is not the correct value.)

M_r .....

.....

Value of x .....

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(5 marks)

3 (c) A 1.37 g sample of a barium compound, **X**, contains 0.835 g of barium and 0.146 g of carbon, the rest being oxygen.

Use these data to calculate the empirical formula of **X**.

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(3 marks)

3 (d) An empirical formula can be used to deduce the molecular formula of a compound.

3 (d) (i) State what is meant by the term *molecular formula*.

.....

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(1 mark)

3 (d) (ii) State the information, other than the empirical formula, that you would need to deduce the molecular formula of a compound.

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(1 mark)

13

Turn over ▶

4 There are trends in the properties of the elements, and of their compounds, both across periods and down groups in the Periodic Table.

4 (a) There is a general increase in the values of the first ionisation energies of the Period 3 elements Na to Ar

4 (a) (i) State the meaning of the term *first ionisation energy* of an element.

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(2 marks)

4 (a) (ii) Explain this general increase in the values of the first ionisation energies.

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(2 marks)

4 (a) (iii) Explain why the value of the first ionisation energy of Al is lower than that of Mg

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(2 marks)

4 (b) There is a trend in the solubility in water of the Group II metal hydroxides.

4 (b) (i) State the observations you would make when dilute aqueous sodium hydroxide is added to separate aqueous solutions of $MgCl_2$ and $BaCl_2$

Observation with $MgCl_2(aq)$ .....

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Observation with $BaCl_2(aq)$ .....

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(2 marks)

4 (b) (ii) Write an ionic equation, including state symbols, for a reaction which occurs in part (b) (i).

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(1 mark)

4 (c) The hydrogen halides contain polar covalent bonds.

4 (c) (i) State what is meant by the term *polar* as it applies to a covalent bond.

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(1 mark)

4 (c) (ii) Explain why the H—Cl bond is more polar than the H—I bond.

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(2 marks)

12

SECTION B

Answer **both** questions in the space provided on pages 12–16.

5 (a) The melting points of the Period 3 elements silicon, sulphur and chlorine are 1683 K, 386 K and 172 K, respectively. Explain, in terms of the structure and bonding present, why the melting point of silicon is very high, and why the melting point of chlorine is lower than that of sulphur. *(7 marks)*

5 (b) Use your knowledge of structure and bonding to deduce why sodium metal can be beaten into shape when hit with a hammer but solid sodium chloride breaks into small pieces. *(3 marks)*

6 A 1.04 g sample of methanol vapour, CH_3OH (M_r = 32.0), was maintained at a pressure of 101 kPa and a temperature of 350 K. Use the ideal gas equation to calculate the volume, in cm^3, that this sample of methanol vapour would occupy under these conditions. (The gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$) *(5 marks)*

END OF QUESTIONS

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