Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
6	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
January 2009

Chemistry CHEM1

Unit 1 Foundation Chemistry

Friday 9 January 2009 1.30 pm to 2.45 pm

For this paper you must have:
- a calculator.

Time allowed
- 1 hour 15 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions 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 that you do not want to be marked.
- The Periodic Table/Data Sheet is provided as an insert.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 70.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

Advice
- You are advised to spend about 50 minutes on **Section A** and about 25 minutes on **Section B**.

SECTION A

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

1 In 1913 Niels Bohr proposed a model of the atom with a central nucleus, made up of protons and neutrons, around which electrons moved in orbits. After further research, the model was refined when the existence of energy levels and sub-levels was recognised.

1 (a) Complete the following table for the particles in the nucleus.

Particle	Relative charge	Relative mass
proton		
neutron		

(2 marks)

1 (b) State the block in the Periodic Table to which the element tungsten, W, belongs.

.....

(1 mark)

1 (c) Isotopes of tungsten include ^{182}W and ^{186}W

1 (c) (i) Deduce the number of protons in ^{182}W

.....

(1 mark)

1 (c) (ii) Deduce the number of neutrons in ^{186}W

.....

(1 mark)

1 (d) In order to detect the isotopes of tungsten using a mass spectrometer, a sample containing the isotopes must be vaporised and then ionised.

1 (d) (i) Give **two** reasons why the sample must be ionised.

1 .....

2 .....

(2 marks)

1 (d) (ii) State what can be adjusted in the mass spectrometer to enable ions formed by the different isotopes to be directed onto the detector.

.....

(1 mark)

1 (e) State and explain the difference, if any, between the chemical properties of the isotopes ^{182}W and ^{186}W

Difference .....

Explanation .....

.....

(2 marks)

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

m/z	182	183	184	186
Relative abundance / %	26.4	14.3	30.7	28.6

Use the data above to calculate a value for the relative atomic mass of this sample of tungsten. Give your answer to 2 decimal places.

.....

.....

.....

(2 marks)

12

2 The table below shows the electronegativity values of some elements.

	H	C	N	O
Electronegativity	2.1	2.5	3.0	3.5

2 (a) State the meaning of the term *electronegativity*.

.....

.....

.....

(2 marks)

2 (b) State the strongest type of intermolecular force in the following compounds.

Methane (CH_4) .....

Ammonia (NH_3) .....

(2 marks)

2 (c) Use the values in the table to explain how the strongest type of intermolecular force arises between two molecules of ammonia.

.....

.....

.....

.....

.....

(3 marks)

2 (d) Phosphorus is in the same group of the Periodic Table as nitrogen.
A molecule of PH_3 reacts with an H^+ ion to form a PH_4^+ ion.
Name the type of bond formed when PH_3 reacts with H^+ and explain how this bond is formed.

Type of bond .....

Explanation .....

.....

.....

(3 marks)

2 (e) Arsenic is in the same group as nitrogen. It forms the compound AsH_3
Draw the shape of an AsH_3 molecule, including any lone pairs of electrons. Name the shape made by its atoms.

Shape

Name of shape .....

(2 marks)

2 (f) The boiling point of AsH_3 is $-62.5\,°C$ and the boiling point of NH_3 is $-33.0\,°C$.
Suggest why the boiling point of AsH_3 is lower than that of NH_3

.....

.....

.....

(1 mark)

2 (g) Balance the following equation which shows how AsH_3 can be made.

..... $AsCl_3$ + ... $NaBH_4$ $\longrightarrow$ ..... AsH_3 + ... NaCl + ... BCl_3

(1 mark)

14

Turn over for the next question

3 Titanium(IV) oxide (TiO_2, $M_r = 79.9$) is used as a white pigment in some paints. The pigment can be made as shown in the following equation.

$$TiCl_4(l) + 2H_2O(l) \longrightarrow TiO_2(s) + 4HCl(aq)$$

3 (a) (i) Calculate the percentage atom economy for the formation of TiO_2

.....

.....

.....

(2 marks)

3 (a) (ii) In view of the low atom economy of this reaction, suggest how a company can maximise its profits without changing the reaction conditions or the production costs.

.....

.....

(1 mark)

3 (b) In an experiment 165 g of $TiCl_4$ were added to an excess of water.

3 (b) (i) Calculate the amount, in moles, of $TiCl_4$ in 165 g.

.....

.....

.....

(2 marks)

3 (b) (ii) Calculate the maximum amount, in moles, of TiO_2 which can be formed in this experiment.

.....

.....

(1 mark)

3 (b) (iii) Calculate the maximum mass of TiO_2 formed in this experiment.

.....

.....

(1 mark)

3 (b) (iv) In this experiment only 63.0 g of TiO_2 were produced. Calculate the percentage yield of TiO_2

.....

.....

.....

(1 mark)

8

Turn over for the next question

4 This question is about the elements in Period 3 from Na to P

4 (a) (i) Explain the meaning of the term *first ionisation energy*.

.....

.....

.....

(2 marks)

4 (a) (ii) State and explain the general trend in first ionisation energies for the elements Na to P

Trend .....

Explanation .....

.....

.....

(3 marks)

4 (a) (iii) State which one of the elements from Na to P deviates from this general trend and explain why this occurs.

Element .....

Explanation .....

.....

.....

(3 marks)

4 (b) State which one of the elements from Na to P has the highest melting point and explain your answer.

Element .....

Explanation .....

.....

.....

(3 marks)

11

5 A metal carbonate MCO_3 reacts with hydrochloric acid as shown in the following equation.

$$MCO_3 + 2HCl \longrightarrow MCl_2 + H_2O + CO_2$$

A 0.548 g sample of MCO_3 reacted completely with 30.7 cm^3 of 0.424 mol dm^{-3} hydrochloric acid.

5 (a) (i) Calculate the amount, in moles, of HCl which reacted with 0.548 g MCO_3

.....

.....

(1 mark)

5 (a) (ii) Calculate the amount, in moles, of MCO_3 in 0.548 g.

.....

.....

(1 mark)

5 (a) (iii) Calculate the relative formula mass of MCO_3

.....

.....

(1 mark)

5 (b) Use your answer from part (a) (iii) to deduce the relative atomic mass of metal M and suggest its identity.
(If you have been unable to calculate a value for the relative formula mass of MCO_3 you should assume it to be 147.6 but this is not the correct answer.)

Relative atomic mass .....

.....

.....

Identity of M .....

(2 marks)

5

SECTION B

Answer Question 6 in the spaces provided on pages 10 to 15.

6 Petrol contains saturated hydrocarbons. Some of the molecules in petrol have the molecular formula C_8H_{18} and are referred to as octanes. These octanes can be obtained from crude oil by fractional distillation and by cracking suitable heavier fractions.

Petrol burns completely in a plentiful supply of air but can undergo incomplete combustion in a car engine.

6 (a) State the meaning of both the words *saturated* and *hydrocarbon* as applied to the term *saturated hydrocarbon*.

Name the homologous series to which C_8H_{18} belongs.

.....

.....

.....

.....

.....

.....

(3 marks)

6 (b) Outline the essential features of the fractional distillation of crude oil that enable the crude oil to be separated into fractions.

.....

.....

.....

.....

.....

.....

.....

.....

(4 marks)

Question 6 continues on the next page

6 (c) C_8H_{18} is obtained by the catalytic cracking of suitable heavy fractions.
State what is meant by the term *cracking* and name the catalyst used in catalytic cracking.

Write an equation to show how one molecule of $C_{14}H_{30}$ is cracked to form one molecule of C_8H_{18} and one molecule of another hydrocarbon.

Explain why oil companies need to crack 'suitable heavy fractions'.

.....

.....

.....

.....

.....

.....

.....

.....

(4 marks)

6 (d) Write an equation for the incomplete combustion of C_8H_{18} to form carbon monoxide and water only.

A catalytic converter is used to remove carbon monoxide from the exhaust gases in a car. Identify a catalyst used in the catalytic converter.

Write an equation to show how carbon monoxide is removed in a catalytic converter.

State why the water produced in the exhaust gases may contribute to global warming.

.....

.....

.....

.....

.....

.....

.....

.....

(4 marks)

Question 6 continues on the next page

6 (e) When some petrol was accidentally contaminated in 2007, the sensors in the affected cars caused a decrease in the supply of petrol to the engine.

Suggest the effect that the contaminated fuel would have on the performance of the cars.

State how the oil company might have recognised the problem before the petrol was sold.

.....

.....

.....

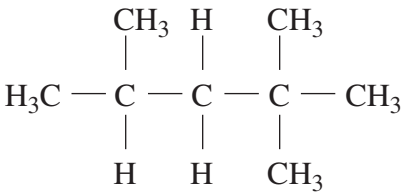
.....

(2 marks)

6 (f) The molecular formula C_8H_{18} represents several structural isomers.

State what is meant by the term *structural isomers*.

Name the following structural isomer of C_8H_{18}



.....

.....

.....

.....

.....

.....

(3 marks)

20

END OF QUESTIONS

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

GCE Chemistry Data Sheet

Table 1
Infrared absorption data

Bond	Wavenumber /cm^{-1}
N—H (amines)	3300 – 3500
O—H (alcohols)	3230 – 3550
C—H	2850 – 3300
O—H (acids)	2500 – 3000
C≡N	2220 – 2260
C=O	1680 – 1750
C=C	1620 – 1680
C—O	1000 – 1300
C—C	750 – 1100

Table 2
^{1}H n.m.r. chemical shift data

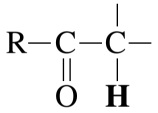
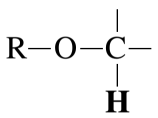
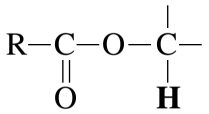
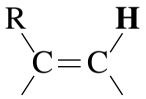
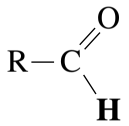
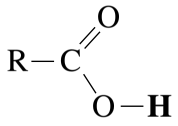
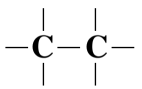
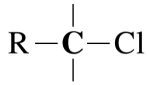
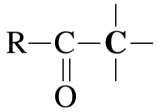
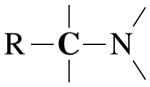
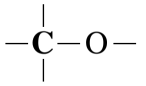
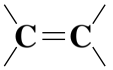
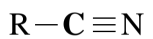
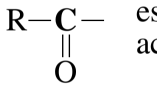
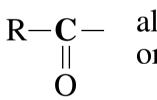
Type of proton	δ/ppm
ROH	0.5 – 5.0
RCH$_3$	0.7 – 1.2
RNH$_2$	1.0 – 4.5
R$_2$CH$_2$	1.2 – 1.4
R$_3$CH	1.4 – 1.6
	2.1 – 2.6
	3.1 – 3.9
RCH$_2$Cl or Br	3.1 – 4.2
	3.7 – 4.1
	4.5 – 6.0
	9.0 – 10.0
	10.0 – 12.0

Table 3
^{13}C n.m.r. chemical shift data

Type of carbon	δ/ppm
	5 – 40
 Cl or Br	10 – 70
	20 – 50
	25 – 60
 alcohols, ethers or esters	50 – 90
	90 – 150
	110 – 125
	110 – 160
 esters or acids	160 – 185
 aldehydes or ketones	190 – 220

The Periodic Table of the Elements

1	2											3	4	5	6	7	0
																	(18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
(1)	(2)		**Key**									(13)	(14)	(15)	(16)	(17)	
6.9 **Li** lithium 3	9.0 **Be** beryllium 4		relative atomic mass **symbol** name atomic (proton) number									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	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 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	96.0 **Mo** molybdenum 42	[98] **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	183.8 **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	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac** † actinium 89	[267] **Rf** rutherfordium 104	[268] **Db** dubnium 105	[271] **Sg** seaborgium 106	[272] **Bh** bohrium 107	[270] **Hs** hassium 108	[276] **Mt** meitnerium 109	[281] **Ds** darmstadtium 110	[280] **Rg** roentgenium 111	Elements with atomic numbers 112-116 have been reported but not fully authenticated						

140.1 **Ce** cerium 58	140.9 **Pr** praseodymium 59	144.2 **Nd** neodymium 60	[145] **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	173.1 **Yb** ytterbium 70	175.0 **Lu** lutetium 71
232.0 **Th** thorium 90	231.0 **Pa** protactinium 91	238.0 **U** uranium 92	[237] **Np** neptunium 93	[244] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[247] **Bk** berkelium 97	[251] **Cf** californium 98	[252] **Es** einsteinium 99	[257] **Fm** fermium 100	[258] **Md** mendelevium 101	[259] **No** nobelium 102	[262] **Lr** lawrencium 103

* **58 – 71** Lanthanides

† **90 – 103** Actinides