WELLINGTON
COLLEGE

16+ ENTRANCE EXAMINATION

CHEMISTRY

Time allowed: 40 minutes

Special Instructions:

- Answer all questions in the spaces provided.
- You will need use of a calculator, and the Periodic Table which can be found at the end of the paper.

Name: ____

Current School: _______________________________________

SECTION A

Write the letter of the correct answer in the box at the end of each question.

1) Element Y forms an ion $\mathbf{Y^{3-}}$ with the electron configuration 2,8,8. To which group and period of the Periodic Table does Y belong?

	Group	Period
A.	3	3
B.	3	4
C.	5	3
D.	5	4
E.	8	3

2) Which of the following could **NOT** be described as a giant structure?

A. sodium chloride
B. diamond
C. graphite
D. magnesium
E. carbon dioxide

3) Three forms of pure carbon are diamond, graphite and Buckminster fullerene. Buckminster fullerene has the formula $\mathbf{C_{60}}$ and is the shape of a soccer ball.

Which one of the following statements applies to **ALL THREE** forms of carbon?

A. Weak intermolecular forces hold the structure together.
B. Carbon atoms are bonded to 4 other carbon atoms.
C. They have similar physical properties.
D. They burn completely in oxygen to form carbon dioxide.
E. They are electrical insulators.

4) Which of the following does not contain covalent bonds?

A. silicon dioxide
B. calcium chloride
C. water
D. ammonia
E. hydrogen sulfide

5) Naturally occurring bromine contains two isotopes with mass numbers 79 and 81. These are present in equal proportions. What fraction of the molecules of bromine, Br_2, would you expect to have a relative mass of 160?

A. ⅓
B. ½
C. ¼
D. ¾
E. 1

6) The average human draws in 0.5 dm^3 of air in a single breath. Assuming air is 78% nitrogen, and that 24 dm^3 of air contains 6×10^{23} molecules, calculate the number of nitrogen atoms taken in with a single breath.

A. 1.25×10^{21}
B. 9.75×10^{21}
C. 1.95×10^{22}
D. 2.50×10^{22}
E. 2.50×10^{23}

7) What values of ***a***, ***b*** and ***c*** are needed to balance the following equation?

$$a\ Pb(NO_3)_2 \rightarrow b\ PbO + c\ NO_2 + O_2$$

	a	*b*	*c*
A.	2	4	4
B.	1	1	2
C.	1	1	4
D.	1	2	2
E.	2	2	4

8) One of the major determiners of reaction speed is the breaking of bonds, so you would expect reactions in which no bonds are broken to be fast at room temperature. Which of the following reactions would you expect to be the fastest at room temperature?

A. $H_2(g) + I_2(g) \rightarrow 2HI(g)$
B. $C_2H_4(g) + Br_2(aq) \rightarrow C_2H_4Br_2(l)$
C. $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$
D. $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$
E. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

9) The order of reactivity of four metal elements is J>M>Q>T, i.e. J is the most reactive and T is the least. A series of reactions is given below:

1	MCl_2 + T	→	TCl_2 + M
2	MSO_4 + J	→	JSO_4 + M
3	TO + Q	→	QO + T
4	QO + J	→	JO + Q
5	JSO_4 + T	→	TSO_4 + J
6	MO + Q	→	QO + M

Which THREE reactions could take place?

A.	1, 2 and 3
B.	2, 3 and 4
C.	3, 4 and 5
D.	4, 5 and 6
E.	1, 4 and 6

10) What values of ***a***, ***b***, ***c*** and ***d*** are needed to balance the following equation?

$$a\,KMnO_4 + b\,HCl \rightarrow a\,KCl + a\,MnCl_2 + c\,H_2O + d\,Cl_2$$

	a	***b***	***c***	***d***
A.	1	8	4	3
B.	1	8	4	4
C.	1	4	2	1
D.	2	16	4	6
E.	2	16	8	5

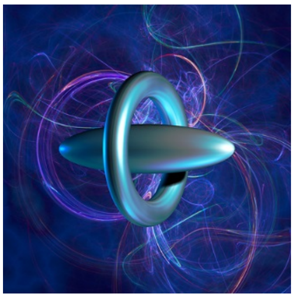
[10 marks]

Section B follows on the next page.

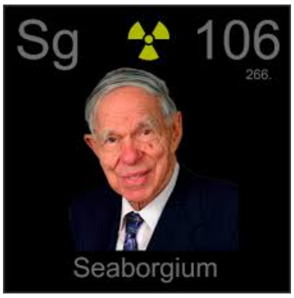
SECTION B

1) In June 1974, 40 years ago this year, Russian scientists in Dubna announced the discovery of element 106. A few months later in September 1974, American scientists working in California also made this element.

The element was eventually named Seaborgium in 1997, the first element to be named after a living chemist, Glenn T. Seaborg. Its symbol is Sg and it is placed directly underneath Tungsten (W) in the Periodic Table.



http://www.rsc.org/periodic-table



http://periodictable.com/Elements

a) The Russian team made isotopes of Sg by firing ^{54}Cr nuclei (all electrons removed) at a piece of lead, isotope ^{208}Pb, to fuse (join) the nuclei together.

i) Write out the complete symbol, including the mass number, atomic number and charge, for the ion of Sg formed in this experiment.

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ii) Two isotopes of Sg had been made in this experiment: ^{261}Sg and ^{260}Sg.

From your understanding of Atomic Structure, deduce how these were formed from the original Sg ion in part *(i)*.

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The American team started with a piece of californium–249 metal and fired oxygen–18 nuclei (8+ charge) at it. They made ions of $^{263}Sg^{8+}$.

Suggest ONE reason why it is difficult to make nuclei of elements such as Sg in the types of process described above. (Ignore any possible **chemical** reactions.)

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b) Seaborgium is found in the Transition Metals section of the Periodic Table underneath chromium, molybdenum and tungsten. The formulae for oxides of these elements are shown in the table.

Chromium	***Molybdenum***	***Tungsten***
	MoO	
CrO_2	MoO_2	WO_2
CrO_3	MoO_3	WO_3
Cr_2O_3		
Cr_3O_4		

i) Suggest the formula(e) of the oxide(s) which are most likely to be expected for seaborgium, Sg.

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ii) All three elements (Cr, Mo and W) have high melting points and are hard metals. Tungsten has the highest melting point of all known metals. Would you expect Seaborgium to have a higher or lower melting point than Tungsten? Explain your answer.

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iii) To extract tungsten from its ores, the ores are first converted to the oxide WO_3. This is then reduced to the metal by heating it in a stream of hydrogen gas at 800^{O}C.

Write a chemical equation for the reduction of WO_3 to tungsten metal.

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Explain why this process is potentially dangerous.

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Suggest why this process forms high purity metal.

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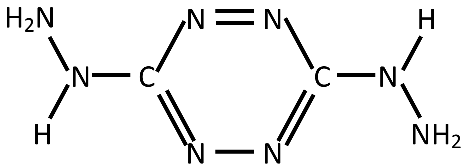
[10 marks]

2) "Bonfire Night" in England is celebrated on November 5th. On that date in 1605, men involved in the Gunpowder Plot planned to blow up the Houses of Parliament when the King would have been present. The plot was discovered before it could be carried out.

Fireworks are a traditional part of the celebrations, as they are for many other occasions around the world. The problem is that they cause a lot of pollution.

Replacing the carbon and hydrogen in fuels by nitrogen can cut the smoke evolved, but many compounds containing mostly nitrogen are dangerously unstable.

a) One compound finding favour as a fuel is ***dihydrazinotetrazine***. The compound is remarkably stable. The molecule's structure is shown below:



i) Write out the molecular formula for dihydrazinotetrazine in the form $C_xH_yN_z$.

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ii) When dihydrazinotetrazine is burnt in excess oxygen, the products are nitrogen and two other substances. Write a balanced equation for this combustion reaction.

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iii) Some average bond energies are listed in the table below. By considering which bonds are broken and made in the reaction, explain why this compound could be expected to be a good fuel for fireworks.

Bond	N–N	N=N	N≡N	N–H	N–C	N=C	O=O	C=O	O–H
Energy (kJ/mol)	158	410	945	391	286	615	498	745	464

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b) Octanitrocubane is another potential fuel. Its structure has a cage of 8 carbon atoms, one at each corner of a cube, with each carbon atom bonded to a nitro group ($–NO_2$).

i) Draw the structure of octanitrocubane.

ii) Use the relative atomic masses on the Periodic Table to calculate the percentage by mass of carbon in octanitrocubane. (Show your working clearly.)

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iii) Give a balanced chemical equation to show that no additional oxygen is required when octanitrocubane is used as a fuel.

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iv) Carbon atoms in diamond or in straight chain alkanes (e.g., propane and butane) have tetrahedral geometry where the bond angle between carbon atoms is approximately 109°.

By considering the C–C–C bond angle in octanitrocubane, suggest why this compound is unstable and difficult to make.

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[14 marks]

3) Chlorine gas, Cl_2, was first prepared and studied by the Swedish chemist, Carl Wilhelm Scheele in 1774. It was not recognised as an element until 1810, when Sir Humphrey Davy repeated some earlier experiments. He named the element chlorine, from the Greek word meaning green-yellow.

The First World War started 100 years ago in 1914. Chlorine was first used as a chemical weapon by the Germans in April 1915 at Ypres. It was also used later by the British army.

a) Chlorine forms several oxides, including dichlorine monoxide, Cl_2O.

Draw a dot-cross diagram to show the bonding in a molecule of dichlorine monoxide, Cl_2O. Show the outer electrons only.

b) One important use for chlorine is in killing harmful bacteria. In 1820s France, long before the germ theory of disease, chlorine dissolved in sodium or calcium hydroxide was used as a disinfectant, e.g., the Paris cholera outbreak of 1832. Despite bad press in recent years, chlorine is now being used as an effective agent in helping to combat the Ebola outbreak in West Africa and elsewhere.

i) Chlorine reacts with water to form two acids; hydrochloric acid, HCl, and chloric (I) acid (old name hypochlorous acid), formula HClO. The reaction is reversible.

Write a balanced equation for the reaction between chlorine and water.

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ii) Commercial bleach is made by reacting chlorine with sodium hydroxide. Two salts are formed. One of them is sodium chloride. Write down the formula of the other salt formed in the reaction.

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iii) Many areas of the world have water supplies which are classed as hard. This type of water often forms limescale (calcium carbonate) which builds up around taps and in kettles and hot water systems. Acidic cleaners are often used to remove limescale from toilets and washbasins. Suggest why it is not safe to use bleach at the same time as an acidic cleaner.

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iv) The World Health Organisation has set a maximum safe level of 5 parts per million (ppm) of chlorine in drinking water. Water supplies in the UK usually contain lower levels, typically 1 ppm (or 1 mg per dm^3).

If 1 mole of chlorine gas at $25^{O}C$ and normal atmospheric pressure occupies a volume of 24 dm^3, calculate what volume of chlorine gas must be added to a tank containing 5000 m^3 of water to give a concentration of 1 ppm. (1 m^3 = 1000 dm^3)

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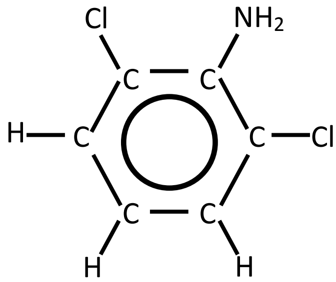
Question 3 continues on the next page.

c) Organic chlorine compounds have been found to be powerful pesticides. One of the most well-known examples is DDT (dichlorodiphenyltrichloroethane). Widespread use of DDT led to environmental problems, in particular almost wiping out some species of birds of prey, including the American bald eagle and the Peregrine falcon in the USA.

Other chlorine compounds are used in medicine. One compound is Diclofenac, an anti-inflammatory drug used to relieve pain in conditions like arthritis.

This drug, used widely in livestock in India, was recently found to be the cause of a catastrophic decline in Asian vulture populations, with numbers of some species dropping by 99% in the last 25 years. Diclofenac causes acute kidney failure in vultures.

One of the starting materials for manufacturing Diclofenac is 2,6–dichloroaniline. The structure of this molecule is shown opposite. The central hexagon with a circle inside represents a benzene ring with six carbon atoms. (Benzene itself has the formula C_6H_6.)



Draw all the possible isomers of 2,6–dichloroaniline where the two chlorine atoms are attached to the benzene ring.

[13 marks]

THE PERIODIC TABLE

Key: Atomic number / **Element** / Relative atomic mass

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** 1.01																	2 **He** 4.00
2	3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.63	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.90
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.96	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
6	55 **Cs** 132.91	56 **Ba** 137.33	57 † **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.20	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** (226)	89 ‡ **Ac** (227)	104 **Rf** (267)	105 **Db** (268)	106 **Sg** (269)	107 **Bh** (270)	108 **Hs** (269)	109 **Mt** (278)	110 **Ds** (281)	111 **Rg** (281)	112 **Cn** (285)	113 **Uut** (286)	114 **Uuq** (289)	115 **Uup** (288)	116 **Uuh** (293)	117 **Uus** (294)	118 **Uuo** (294)

†	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
‡	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)