Rugby School

Sixth Form Entrance Examination

Specimen Paper

CHEMISTRY

Time allowed: 60 minutes

Chemistry Data Sheet

1. Reactivity Series of Metals

Potassium	most reactive
Sodium	
Calcium	
Magnesium	
Aluminium	
Carbon	
Zinc	
Iron	
Tin	
Lead	
Hydrogen	
Copper	
Silver	
Gold	
Platinum	least reactive

(elements in italics, though non-metals, have been included for comparison)

2. Formulae of Some Common Ions

Positive ions		Negative ions	
Name	Formula	Name	Formula
Hydrogen	H^+	Chloride	Cl^-
Sodium	Na^+	Bromide	Br^-
Silver	Ag^+	Fluoride	F^-
Potassium	K^+	Iodide	I^-
Lithium	Li^+	Hydroxide	OH^-
Ammonium	NH_4^+	Nitrate	NO_3^-
Barium	Ba^{2+}	Oxide	O^{2-}
Calcium	Ca^{2+}	Sulfide	S^{2-}
Copper(II)	Cu^{2+}	Sulfate	SO_4^{2-}
Magnesium	Mg^{2+}	Carbonate	CO_3^{2-}
Zinc	Zn^{2+}		
Lead	Pb^{2+}		
Iron(II)	Fe^{2+}		
Iron(III)	Fe^{3+}		
Aluminium	Al^{3+}		

THE PERIODIC TABLE

Period	1	2											3	4	5	6	7	0
	Group																	
1	1 H Hydrogen 1																	4 He Helium 2
2	7 Li Lithium 3	9 Be Beryllium 4											11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10
3	23 Na Sodium 11	24 Mg Magnesium 12											27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulphur 16	35.5 Cl Chlorine 17	40 Ar Argon 18
4	39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	63.5 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36
5	86 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	99 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
6	133 Cs Caesium 55	137 Ba Barium 56	139 La Lanthanum 57	179 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	210 Po Polonium 84	210 At Astatine 85	222 Rn Radon 86
7	223 Fr Francium 87	226 Ra Radium 88	227 Ac Actinium 89															

Key

Relative atomic mass
Symbol
Name
Atomic number

SECTION A

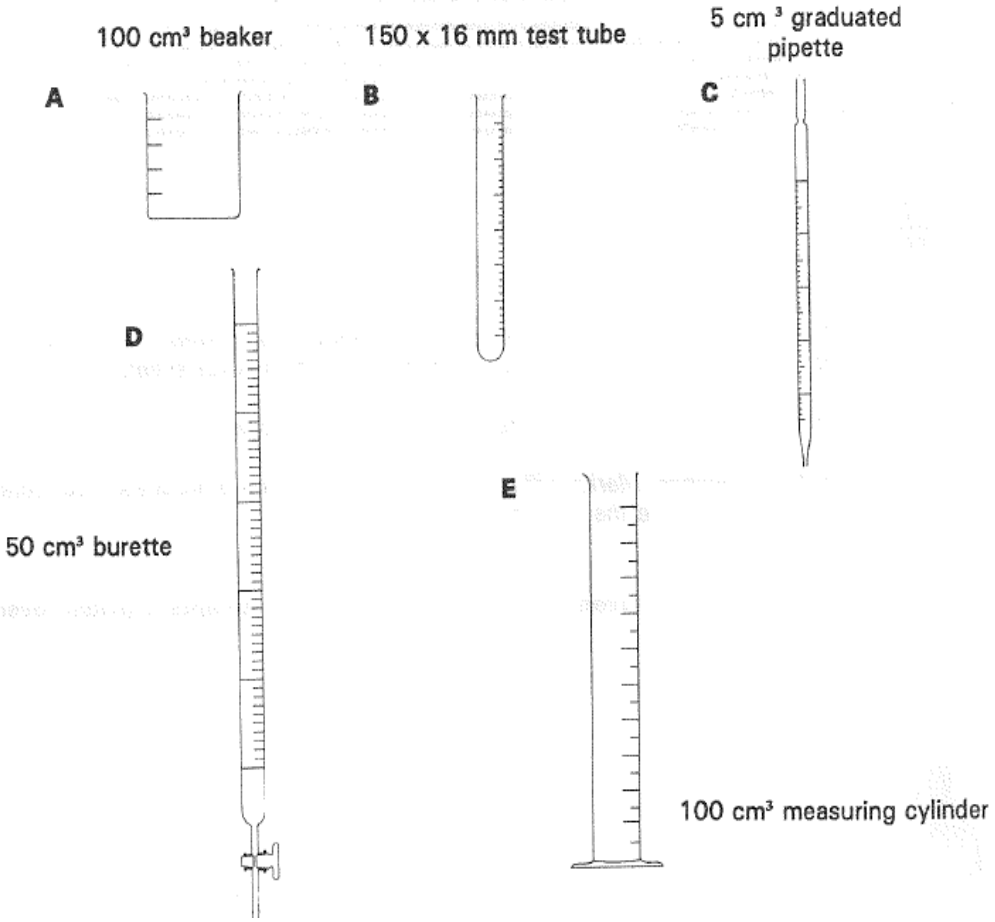
Use the attached 'Multiple Choice Answer Sheet' at the back of this booklet to give your answer to the following multiple questions. You may detach the sheet but remember to write your name and school in the space provided.

Indicate your answer by joining the dots under your chosen letter using a dark (HB) pencil. Ensure you have only one clear answer for each question.

1 Which one of the following methods should be used to compare two ink samples removed from a suspected forged cheque?

A centrifuging
B chromatography
C crystallisation
D distillation
E filtration

2 Which of the following pieces of apparatus is most accurate for measuring out 25.0 cm^3 of solution?

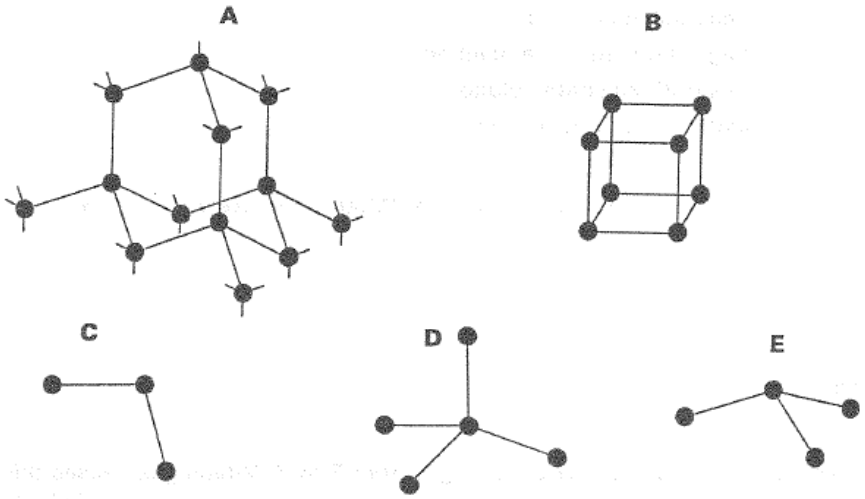


3 Each line of the table below gives the atomic structure of a particle.
Which line shows the structure of one atom of mass number 9?

	Atomic Structure		
	Neutrons	Protons	Electrons
A	12	12	12
B	5	4	4
C	22	18	18
D	18	17	17
E	20	19	19

Questions 4 and 5 refer to the diagrams below

The diagrams are of three-dimensional structures in which the dots represent the centres of atoms or ions.



4 Which diagram shows the arrangement of ions in a sodium chloride crystal?

5 Which diagram best shows the arrangement of atoms in a diamond lattice?

6 The table below gives the melting points and boiling points of five elements. Which element is a liquid at 1000 °C?

	Element	Melting Point /°C	Boiling Point /°C
A	aluminium	660	2470
B	bromine	−7	59
C	chlorine	−101	−35
D	iron	1540	2750
E	mercury	−39	357

7 Which one of the following shows the mass of each element present in one mole of aluminium oxide (Al_2O_3)?

	Mass of aluminium /g	Mass of oxygen /g
A	2	3
B	27	16
C	48	58
D	54	48
E	81	32

8 When air dissolves in water the pH changes from 7 to 6. Which gas causes this change?

A argon
B carbon dioxide
C hydrogen
D nitrogen
E oxygen

9 Solid sodium chloride does not conduct electricity.
Aqueous sodium chloride does. This is because

A no solids conduct electricity.
B only liquids conduct electricity.
C water molecules conduct the electricity.
D the water allows the sodium chloride molecules to move.
E moving ions from the sodium chloride conduct the electricity.

10 Which one of the following shows the results of the electrolysis of dilute sulphuric acid using inert electrodes?

	At the anode (+)	At the cathode (−)
A	hydrogen	oxygen
B	hydrogen	sulphur
C	oxygen	hydrogen
D	sulphur	oxygen
E	oxygen	sulphur dioxide

11 An alkali dissolves in water to form a solution containing

A carbonate ions

B hydrogen ions

C hydroxide ions

D oxide ions

12 Which halogen is the most reactive?

A Chlorine

B Fluorine

C Iodine

D Bromine

13 Carbon is used to extract certain metals from their ores. In these reactions carbon is acting as a reducing agent. This means that carbon

A reduces the volume of the ore

B reduces the amount of impurities in the ore

C removes the oxygen from the ore

D mixes with the metal to make it harder

14 An element X reacts with the oxide of element Y but not with the oxide of element Z. Which of the following show the elements in decreasing order of reactivity?

A XYZ

B YZX

C ZXY

D ZYX

15 Which one of the following could a gardener use to reduce acidity in the soil?

A sodium chloride

B calcium carbonate

C ammonium nitrate

D copper sulphate

16 The boiling points of four alkanes are shown in the table below:

Name	Formula	Boiling point (°C)
methane	CH_4	-164
propane	C_3H_8	-42
pentane	C_5H_{12}	36
heptane	C_7H_{16}	98

What conclusion can you make from this information?

A heptane is a gas at room temperature

B methane cannot be liquefied

C the bigger the molecules, the higher the boiling point

D methane has a higher boiling point than propane

17 Nitrogen and hydrogen are used to manufacture ammonia

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

The equation shows that the reaction is

A slow

B exothermic

C catalysed

D reversible

18 What is the best description of stainless steel?

A alloy of Fe & Cr

B alloy of Fe & C

C compound of Fe & Cr

D compound of Fe & C

19 Saturated alkanes such as ethane

A decolourise bromine water in the dark

B react with hydrogen

C can be polymerised

D produce carbon monoxide when burnt in a limited supply of air

20 Which one of the following turns pink when water is added to it?

A anhydrous copper(II) sulphate

B blue cobalt(II) chloride

C blue litmus solution

D universal indicator solution

The END of Section A

Section B

Q1

a Hydrogen is the most abundant element in the universe. It is predominantly found as the ^{1}H isotope, but also exists as ^{2}H (known as deuterium) and ^{3}H (called tritium).

(i) What is meant by the term *isotope*?

……

……

(2)

(ii) Complete the table below to give the numbers of protons, neutrons and electrons present in each of the three different isotopes of hydrogen.

Isotope	No. of protons	No. of neutrons	No. of electrons
$^{1}_{1}H$			
$^{2}_{1}H$			
$^{3}_{1}H$			

(3)

b Hydrogen is a colourless, odourless gas. In the laboratory it is made by reacting a metal, such as zinc, with dilute sulfuric acid. On an industrial scale it is made by the reaction of methane and steam.

(i) Name the product, other than hydrogen, that is formed when zinc reacts with sulfuric acid.

……

(1)

(ii) Describe a simple test for hydrogen gas.

……

(2)

(iii) Why would you not use with copper or sodium to make hydrogen gas?

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(2)

(iv) The word equation for the reaction of methane with steam is as follows:

$$\text{methane} + \text{steam} \rightarrow \text{carbon monoxide} + \text{hydrogen}$$

Convert this word equation into a balanced symbol equation.

……

……

(2)

(v) The carbon monoxide from this reaction is then reacted with more steam converting it into carbon dioxide and more hydrogen. Construct a balanced symbol equation for this reaction.

……

(1)

(vi) Explain why the reaction between carbon monoxide and steam can be called a redox reaction.

……

……

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(2)

c One of the main uses of hydrogen is in the manufacture of ammonia (NH_3) *via* the Haber Process. In this process hydrogen is reacted with nitrogen at 450 ^oC and 250 atm pressure in the presence of an iron catalyst.

$$\text{nitrogen} + \text{hydrogen} \rightleftharpoons \text{ammonia}$$

(i) What is the main source of nitrogen for this process?

……

(1)

(ii) Construct a balanced symbol equation for this reaction

……

……

(2)

(iii) The iron is a catalyst for this reaction. What do you understand by the term *catalyst*?

……

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(2)

(Total 20)

Q2

Alcohols, like alkanes and alkenes, are good fuels and burn in air to form carbon dioxide and water.

a Suggest <u>two</u> qualities that you would expect a good fuel to have

……

……

(2)

b Name one other product that might be formed if the air supply to the burning alcohol is restricted?

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(1)

c In an experiment to determine the energy given out when methanol (CH_3OH) is burnt, 0.24g of methanol was placed in a crucible under a metal can that contained 100g of water. The initial temperature of the water was measured and found to be 19.0^{o}C. The methanol was then ignited and the water in the metal can stirred and the temperature monitored until all of the alcohol had burnt. The final temperature of the water, after all of the alcohol had burnt, was 32.5^{o}C.

The energy transferred to the water in the can is given by the equation:

Energy transferred = m x c x ΔT

Where m = the mass of the water (in g)

c = the specific heat capacity of water = 4.2 J/g ^{o}C

ΔT = the change in the temperature of the water (in ^{o}C)

The energy given out when an alcohol is burnt is usually quoted in kJ/mol. This is given by the equation:

$$\text{Energy given out} = \frac{\text{energy transferred}}{\text{no. of moles of alcohol burnt}}$$

$$\text{No. of moles} = \frac{\text{mass of alcohol}}{\text{relative molecular mass of alcohol}}$$

(i) Calculate the change in temperature of the water

……

(1)

(ii) Calculate the energy transferred (in J) to the water when the methanol was burnt

……

……

(1)

(iii) Calculate the number of moles of methanol that was burnt during this reaction.
(A_r = C (12), H (1), O (16))

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(1)

(iv) Therefore determine the energy given out (in kJ/mol) when methanol is burnt.

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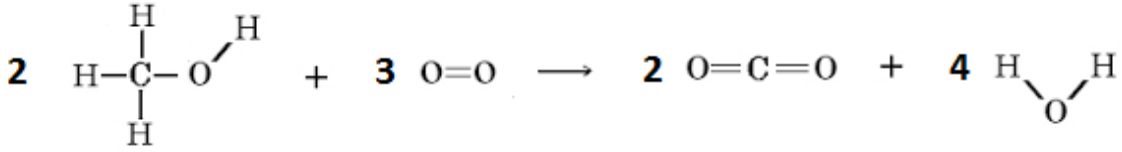
(1)

d A theoretical value for the energy released during the combustion can be obtained by using bond energies. The values for some bond energies are given in the table below:

Bond	C-H	C-O	O=O	O-H	C=O
Bond energy (kJ/mol)	412	360	496	462	743

The equation for the combustion of methanol can be represented as



(i) Work out the energy needed to break all of the bonds in the reaction

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(2)

(ii) Work out the energy released when the bonds are formed in the products

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(2)

(iii) Hence, determine the overall energy change for the reaction.

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(1)

(iv) Explain why the overall reaction is exothermic.

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(1)

e Compare the value obtained by the experiment in part (c) and that calculated in part (d). Briefly explain why the values differ.

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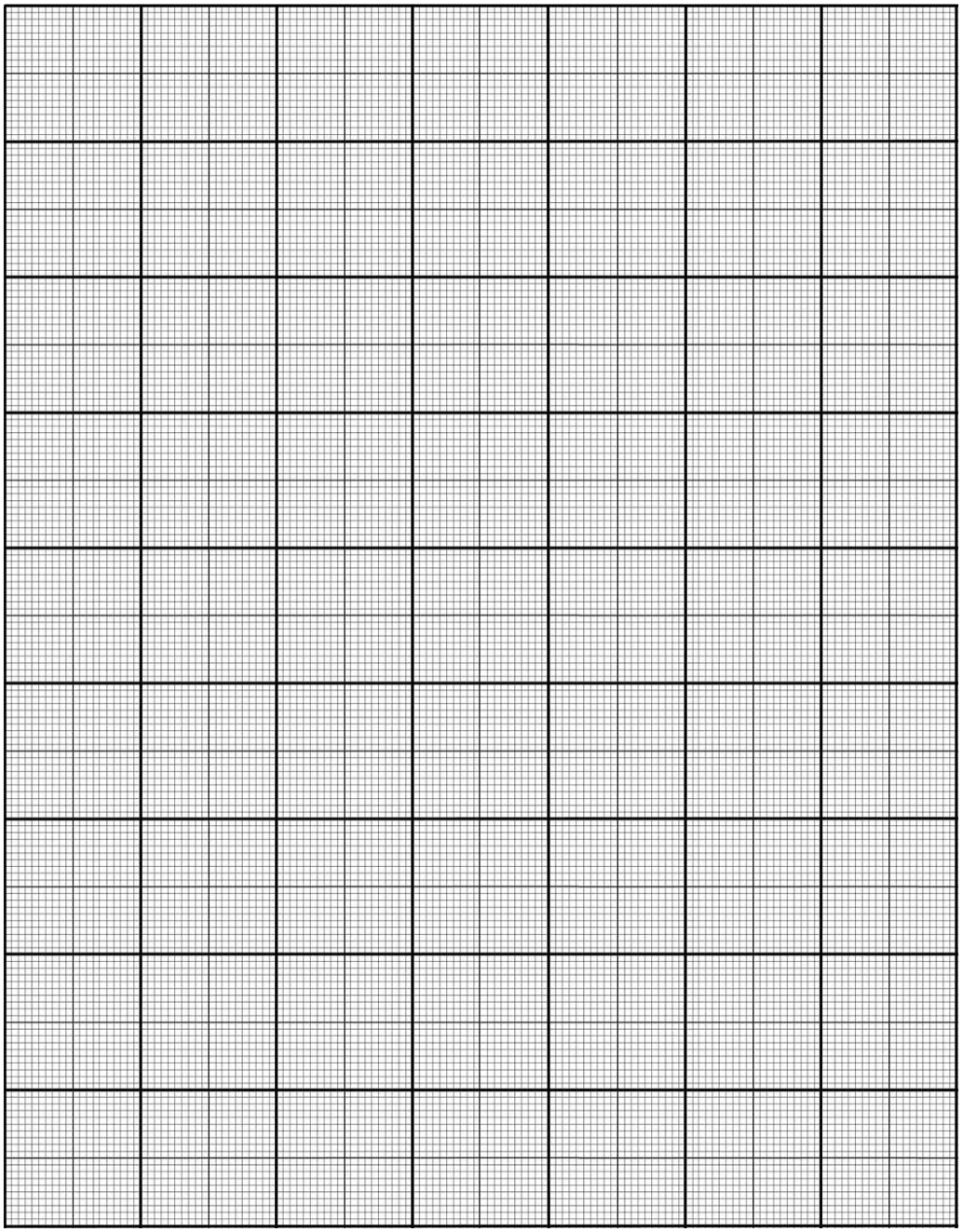
(2)

f The theoretical values for the energy given out when some other alcohols are burnt are given in the table below:

Alcohol	Energy Given Out (kJ/mol)
Ethanol (CH_3CH_2OH)	1371
Propanol ($CH_3CH_2CH_2OH$)	2010
Butanol ($CH_3CH_2CH_2CH_2OH$)	2678
Pentanol ($CH_3CH_2CH_2CH_2CH_2OH$)	3300

(i) Plot a graph of energy given out against the number of carbon atoms in the alcohol.



(4)

(ii) What conclusions can you draw from your graph?

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(1)

(TOTAL 20)

The END of Section B