Chemistry

SAMPLE

Examination Paper

Answer ALL questions.

Clearly cross out surplus answers.

Time: 2 hours

The maximum mark for this paper is 100.

Any reference material brought into the examination room must be handed to the invigilator before the start of the examination.

Marks

Answer ALL questions

Question 1

a) Elements are the simplest chemical substances and are made up of atoms. Atoms contain three simple sub-atomic particles: protons, neutrons and electrons. The protons and neutrons are found in the nucleus and the electrons travel around the nucleus.

i) According to Quantum Mechanics, what is the name given to area of the atom where there is a high possibility of finding an electron? **1**

ii) The electrons in these areas have to obey the Pauli exclusion principle. What does this principle state? **1**

b) The two main isotopes of carbon are ^{12}C and ^{13}C.

i) What is the definition of an isotope? **1**

ii) Copy the table below and for each isotope give the number of protons, electrons and neutrons. **4**

Isotope	Number of protons	Number of neutrons	Number of electrons
^{12}C			6
^{13}C	6		

Isotope	Number of protons	Number of neutrons	Number of electrons
^{12}C	***6***	***6***	6
^{13}C	6	***7***	***6***

iii) Calculate the number of carbon atoms in 32g of carbon solid. **2**

c) The three main trends in the Periodic Table are atomic size (radii), ionisation energy and electronegativity.

i) Define the term “first ionisation energy”. **1**

Marks

ii) Write the equation for the 1st ionisation of one mole of lithium atoms in the gaseous state to form one mole of gaseous lithium ions. **2**

iii) Describe and explain what happens to the size of an atom going across a period. **2**

d) Electronegativity values can be used to infer the type of bonding that might be present in a compound. Some electronegativity values can be seen in the table below.

Element	**Electronegativity (Pauling Scale)**
Li	1.0
Na	0.9
K	0.8
F	4.0
Cl	3.0
Br	2.8

i) Use the table above to find out which compound will have bonds with the most ionic character. Work out an actual overall electronegativity value for the bond in this compound. **2**

ii) Intermolecular forces can be found in a number of covalent compounds. What is the name of the main intermolecular force found in water? **1**

iii) The electronic structure and shape of various covalent molecules, like beryllium fluoride, can be worked out using a number of theories. Draw a Lewis dot/cross diagram for beryllium fluoride and work out the shape of the molecule using the VSEPR theory. Show ALL of the outer electrons in the Lewis diagram. **3**

Total 20 Marks

Question 2

a) Ammonia gas (NH_3) is produced by the Haber process. This involves a reversible reaction with hydrogen and nitrogen gases acting as the reactants. The production of ammonia is an exothermic process.

i) Write a balanced equation for the formation of ammonia. Include state symbols. **2**

ii) The Haber process is described as being in equilibrium. What does this mean? **2**

Marks

iii) Iron is used as a catalyst in the Haber process. **1**
What term can be used to describe this type of catalyst?

iv) A small scale production was carried out in a one litre flask. The following concentrations were found at equilibrium: N_2 (4 mol.l^{-1}), H_2 (2 mol.l^{-1}) and NH_3 (6 mol.l^{-1}) **3**

Write an equilibrium constant equation for the process and then use the data to calculate the equilibrium constant K (with units) for the reaction.

v) The Haber process is governed by Le Chatelier's principle. Define this principle. **1**

Marks

v) Explain, in detail, what would happen to the yield of ammonia if 1) the pressure was increased, and 2) the temperature increased. **4**

b) The Haber process is an exothermic process. Use the following table of bond enthalpies to work out the overall enthalpy value for the Haber Process. **3**

Bond	**Bond enthalpy ($kJmol^{-1}$)**
$N \equiv N$	945
$N-H$	388
$H-H$	436

c) Ammonia gas dissolves in water to form a ‘weak base’ solution. The chemical reaction for this is: $NH_{3(g)} + H_2O_{(l)} \rightleftharpoons NH_4OH_{(aq)}$

i) Define what is meant by a ‘weak base’. **2**

ii) As well as weak bases there are weak acids. Ethanoic acid (CH_3COOH) is found in vinegar and is a weak acid. Calculate the pH of a 0.135 $mol.l^{-1}$ solution of ethanoic acid if its ka is 1.7×10^{-5}. **2**

Total 20 Marks

Marks

Question 3

a) Transition metal elements and the complexes they form play a crucial role in chemistry.

i) What is the definition of a transition metal? **1**

ii) State the electronic configuration (spectroscopic) for Ni^{2+}. **1**

iii) The level of nickel ions in a solution can be calculated using a complexometric titration. In a titration, a 20.0 cm^3 sample of a nickel(ii) ion solution required 17.0 cm^3 of 0.1 mol. l^{-1} EDTA to completely react with all the nickel(ii) ions. **3**

What is the concentration of the nickel (ii) ion solution in mol.l^{-1}?

iv) Like nickel, manganese is a transition metal with many oxidation states. Complete the table by working out the oxidation state of manganese in each of these different chemical species. **2**

Chemical species	**Oxidation state**
$KMnO_4$	
MnO	

Chemical species	**Oxidation state**
$KMnO_4$	***7+***
MnO	***2+***

b) Transition metal ions are found at the centre of many transition metal complexes where they are attached to ligands.

i) What type of bond do ligands form with the transition metals ions in these complexes? **1**

Marks

ii) Complete the following table which contains information about a number of different transition metal-ligand complexes. **3**

Formula of transition metal-ligand complex	**Name**
$Na_3[Fe(CN)_6]$	
	Tetraamminecopper (II) chloride
$[Ni(NH_3)_6]Cl_2$	

c) Explain how transition metal complexes can be coloured. **4**

d) Nickel can be used as a catalyst in a number of organic reactions.

i) Ethene (C_2H_4) can be converted into ethane (C_2H_6) using hydrogen and the catalyst nickel. What type of reaction is this? **1**

ii) Ethene can also undergo a bromination reaction to form 1,2-dibromoethane. Write a mechanism for this reaction. **4**

Total 20 Marks

Marks

Question 4

a) Calcium carbonate reacts with hydrochloric acid to give calcium chloride, carbon dioxide and water. In the reaction 10g of calcium carbonate powder was reacted with 50 cm^3 of 0.1 $mol.l^{-1}$ hydrochloric acid.

$$CaCO_{3\ (s)} + 2HCl_{\ (aq)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

i) How many moles of calcium carbonate and hydrochloric acid were involved in this reaction? Show all of your working. **4**

ii) The following results were obtained from the reaction. Work out the rate of reaction between two and four minutes. **2**

Time **(minutes)**	0	2	4	6	8	10
Total volume of carbon dioxide production **(cm^3)**	0	42	68	78	92	104

iii) What individual changes could you make to the reaction set-up in order to decrease the rate of this reaction? **3**

iv) Explain how the changes in iii) would slow down the rate of the reaction. **1**

b) Reactions can be termed as either exothermic or endothermic. The following reaction is exothermic.

$$H_{2\ (g)} + O_{2\ (g)} \longrightarrow H_2O_{\ (l)}$$

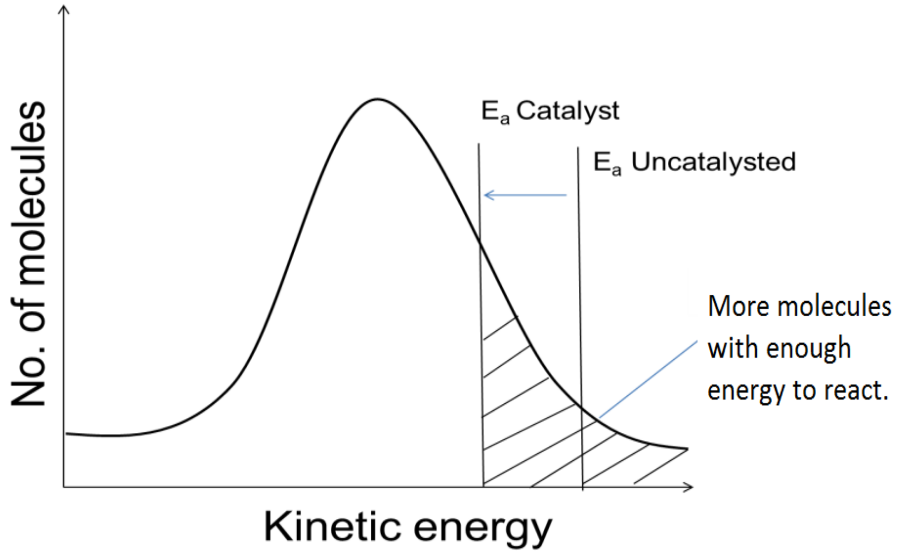
i) What is meant by the term exothermic? **1**

Marks

ii) Draw a diagram representing the range of molecular energies in a gas. **2**

iii) On the same diagram, draw a curve to represent the energies of the gas molecules when the temperature is increased by 10ºC. **1**

iv) Platinum can be used as a catalyst in this reaction. Use your diagram, adding on any features you think appropriate, to explain the effect a catalyst has on the rate of the reaction. **2**



v) Explain why a catalyst has no effect on the enthalpy (heat) of reaction. **1**

c) Reaction rate data can be used to investigate the kinetics of a chemical reaction. Below are the results from a kinetics experiment on the reaction between acidified potassium permanganate ($H^+/KMnO_4$) and hydrogen peroxide (H_2O_2).

Concentration of H_2O_2 (mol.l^{-1})	**Concentration of $H^+/KMnO_4$ (mol.l^{-1})**	**Initial Rate (mol.l^{-1}s^{-1})**
0.02	0.20	6.0×10^{-5}
0.02	0.40	1.2×10^{-4}
0.04	0.20	1.2×10^{-4}

i) What is the overall order of the reaction? **1**

ii) Write a rate equation for this reaction. **1**

iii) Use the information in the table above to work out a value for k. **1**

Total: 20 marks

Marks

Marks

Question 5

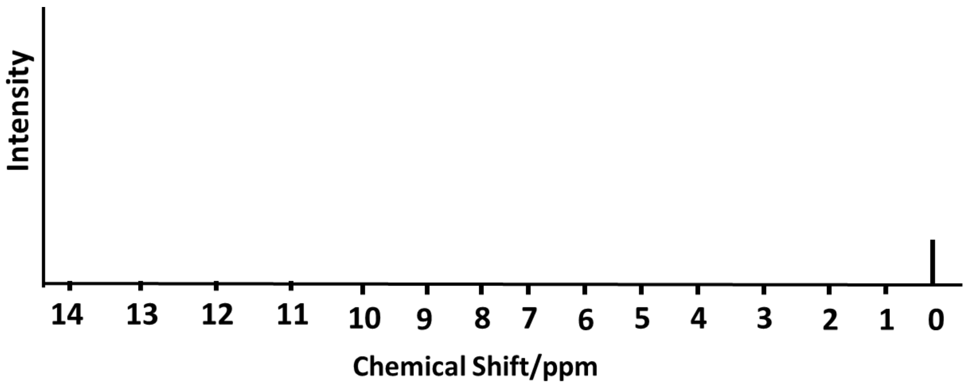
a) A chemistry student finds a bottle with just the molecular formula, $C_3H_6O_2$, written on it. She is not sure whether the compound in the bottle is ethylethanoate or propanoic acid.

i) Draw full structural formulae for both compounds. **2**

ii) Chemical analysis was carried out on the sample in the bottle. ^{1}H-NMR spectroscopy was chosen. **4**

Draw out the ^{1}H-NMR spectrum diagram and complete it to show what the high resolution ^{1}H-NMR spectra for propanoic acid would look. Make sure you have information about any splitting and include the reference compound TMS.

You may wish to use the chemical shift table found in the data sheet at the end of your examination paper.



iii) A simple chemical test could also be used to tell the two suspected compounds apart. Suggest a simple chemical test that the chemist could have used. What observations would be made with each compound? **3**

iv) Ethyl ethanoate and propanoic acid do not contain a chiral carbon centre. What is a chiral centre? **1**

v) Propanoic acid can be changed into propanal and propan-1-ol. **2**
What type of reaction is this and what reagent would be used to carry it out?

b) Benzene is an aromatic compound that is found in a variety of different medicines, including aspirin. It can undergo a variety of electrophilic substitution reactions.

i) What shape is the benzene molecule? **1**

Marks

ii) Give the reagents and conditions necessary for the conversion of benzene to nitrobenzene. **2**

iii) Write a mechanism for this reaction using curly arrows. Explain what is happening at each stage including the formation of any ions. **5**

Total 20 Marks

End of paper

Periodic Table with the mass number and atomic number of each element.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.008																	2 **He** 4.0026
3 **Li** 6.94	4 **Be** 9.0122											5 **B** 10.81	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.085	15 **P** 30.974	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.867	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.845	27 **Co** 58.933	28 **Ni** 58.693	29 **Cu** 63.546	30 **Zn** 65.38	31 **Ga** 69.723	32 **Ge** 72.630	33 **As** 74.922	34 **Se** 78.97	35 **Br** 79.904	36 **Kr** 83.798
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.95	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
55 **Cs** 132.91	56 **Ba** 137.33	57-71 *	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** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89-103 #	104 **Rf** (265)	105 **Db** (268)	106 **Sg** (271)	107 **Bh** (270)	108 **Hs** (277)	109 **Mt** (276)	110 **Ds** (281)	111 **Rg** (280)	112 **Cn** (285)	113 **Nh** (286)	114 **Fl** (289)	115 **MC** (289)	116 **Lv** (293)	117 **Ts** (294)	118 **Og** (294)

* Lanthanide series	57 **La** 138.91	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
# Actinide Series	89 **Ac** (227)	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)

Nuclear Magnetic Spectroscopy data table

Approximate proton chemical shift values (δ) relative to TMS peak (0 on the scale)

Type of proton	Chemical Shift (ppm)
R----**CH_3**	0.9-1.1
R----**CH_2**----R	1.31.5
O H_3C---C O R**CH_2**-C O R_2**HC**--C Aldehyde, Ketone, CAcid and Ester fragment	2.0-.2.7
H_2**C=C**	4.8-5.0
R----CH_2---**X**	3.2-4.3
R----**OH**	4.0-4.5
R------**COOH**	11.0-11.3
R----**CHO**	9.8-10.2
Ar----CH_3	2.3-3.0
Ar----OH	7.0-7.3
Ar----H	7.4-7.6

R = alkyl group
Ar = aryl (aromatic) group
X = halogen

Infrared Spectroscopy data table

Type of bond	Type of compound	Wave number range (cm^{-1})
hydrogen bonded O − H stretch not hydrogen bonded O − H stretch	Alcohol	3200 to 3570 33590 to 3570
C − H stretch C − H bend	Alkane	2853 to 2962 1340 to 1485
C − H stretch in C = C – H C = C stretch	Alkene	3010 to 3095 1620 to 1680
C=O stretch	Aldehyde, Ketones, Carboxylic acids and Esters	1680 to 1750
hydrogen bonded O − H stretch in −COOH	Carboxylic acids	2500 to 3500
C-Br C-Cl	Halogenalkanes	500 to 600 650-800
C − H stretch	benzene ring	3000 to 3100

Formulae

$\Delta H = c \times m \times \Delta T$ (4·18 kJ kg^{-1} ºC^{-1})

$\% \text{ yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$

$\% \text{ atom economy} = \frac{\text{Mass of desired product(s)}}{\text{Total mass of reactants}} \times 100$

$n = c \times V$

$\frac{C_1 \times V_1}{n_1} = \frac{C_2 \times V_2}{n_2}$

$n = m \times GFM$

$\text{rate} = \frac{\Delta \text{quantity}}{\Delta \text{ time}}$

$pH + pOH = 14$

$pH = \log_{10} [H^+]$

$K_w = [H^+] \times [OH^-]$

$pK_a = \log_{10} K_a$

$pH = 1/2\ pK_a - 1/2 \log_{10} [\text{Concentration}]$

Physical constants

Avogadro’s Constant 6·02 × 10^{23} mol^{-1}
Charge on electron 1·60 × 10^{-19} C