Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | | | | | |

Candidate Number | | | | |

Pearson Edexcel Level 3 GCE

Time 2 hours 30 minutes

Paper reference **9CH0/03**

Chemistry

Advanced

PAPER 3: General and Practical Principles in Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 120.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

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Answer ALL questions.

Write your answers in the spaces provided.

1 Relative atomic mass is an important concept in chemistry.

(a) Define the term relative atomic mass.

(2)

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(b) A sample of neon consisted of three isotopes.

Isotope	Percentage abundance
^{20}Ne	84.80
^{21}Ne	2.26
^{22}Ne	12.94

Calculate the relative atomic mass of neon in this sample.
Give your answer to three significant figures.

(2)

(Total for Question 1 = 4 marks)

2 Ammonium cobalt(II) sulfate is made by mixing aqueous solutions of ammonium sulfate and excess cobalt(II) sulfate.

(a) Dry crystals of ammonium cobalt(II) sulfate, $(NH_4)_2SO_4{\cdot}CoSO_4{\cdot}6H_2O$, are obtained by the procedure shown.

Step **1** The reaction mixture is transferred to an evaporating basin, heated gently and then left to crystallise.

Step **2** The crystals are separated by gravity filtration.

Step **3** The crystals are then **rinsed** with a small amount of **ice-cold** water.

Step **4** The rinsed crystals are placed in a **warm oven** for 30 minutes.

(i) The colour of the cobalt(II) sulfate solution used is pink due to the complex cobalt(II) ion, $[Co(H_2O)_6]^{2+}$.

Explain why the solution is coloured.

(4)

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(ii) Explain the shape of the cobalt(II) ion, $[Co(H_2O)_6]^{2+}$, using electron-pair repulsion theory.

(3)

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(iii) Give the reasons for carrying out Steps **3** and **4** of the procedure, referring particularly to the words in bold.

(3)

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(b) The percentage yield of this reaction is 70.0 %.

Give **two** possible reasons, other than an incomplete reaction, why the yield is less than 100 %.

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(Total for Question 2 = 12 marks)

3 A group of students design and carry out experiments to deduce the formulae of two salts, **X** and **Y**.

X contains one cation and one anion.

Y contains water of crystallisation.

(a) (i) A flame test is carried out on **X**.

Describe how to carry out a flame test.

(3)

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(ii) The colour of the flame is yellow.

Give the **formula** of the metal ion present in salt **X**.

(1)

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(b) A sample of **X** is placed in a test tube and dissolved in deionised water. The solution is acidified with hydrochloric acid and barium chloride solution is added.

A white precipitate forms.

(i) Give the **formula** of the anion present in **X**.

(1)

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(ii) Deduce the **formula** of **X**, using your answers to (a)(ii) and (b)(i).

(1)

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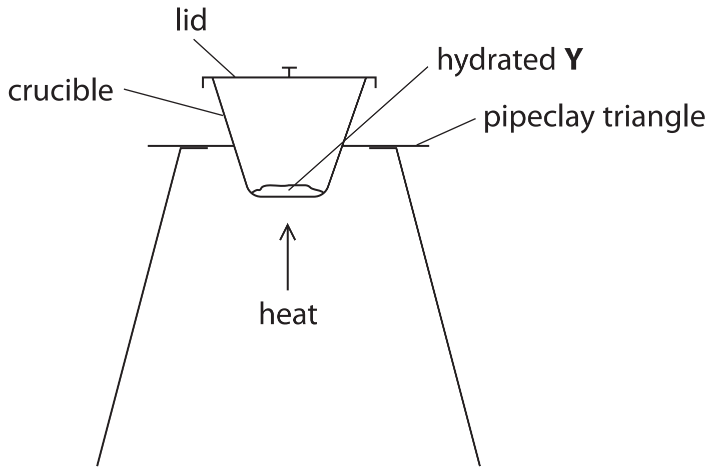
(c) **Y** is identified as hydrated potassium carbonate, $K_2CO_3{\cdot}nH_2O$.

Two of the students were asked to determine the number of moles of water of crystallisation, *n*, in **Y** using the procedure shown:

- weigh a sample of hydrated **Y** into a pre-weighed crucible
- place a lid loosely on the crucible and heat it for five minutes to remove the water of crystallisation
- allow the crucible and lid to cool, remove the lid and then reweigh the crucible with its contents.



(i) The first student carried out the experiment but forgot to use the lid.

Explain how this mistake would affect the calculated value of *n*.

(2)

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(ii) The second student carried out the experiment but heated the apparatus for only **one** minute.

Explain how this mistake would affect the calculated value of *n*.

(2)

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(iii) In an accurate experiment, **Y** is found to consist of 71.9 % K_2CO_3 by mass.

Calculate the value of *n*.

(3)

(Total for Question 3 = 13 marks)

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4 This question is about the white solid barium carbonate.

(a) Barium carbonate decomposes under suitable conditions to form barium oxide and carbon dioxide.

$$BaCO_3(s) \rightarrow BaO(s) + CO_2(g) \qquad \Delta_r H^{\ominus} = +169.3\,\text{kJ mol}^{-1}$$

Standard molar entropy data related to this reaction are shown.

Substance	Standard molar entropy, $S^{\ominus}$ / $\text{J K}^{-1}\,\text{mol}^{-1}$
$BaCO_3(s)$	112.1
$BaO(s)$	70.4
$CO_2(g)$	213.6

(i) Show that barium carbonate is thermally stable at 298 K, using the data in the equation and in the table.

(5)

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(ii) Calculate the lowest temperature, in °C, at which it is thermodynamically feasible for barium carbonate to decompose.
Give your answer to three significant figures.

(3)

(b) Explain whether magnesium carbonate is more or less thermally stable than barium carbonate.

(3)

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(c) A white solid was thought to be barium carbonate. A student suggested that the presence of the carbonate ion could be tested for by adding a small amount of sulfuric acid.

Explain whether or not this suggestion is valid.

(2)

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(Total for Question 4 = 13 marks)

***5** Explain the difference in the reactivity of bromine with benzene and with phenol.

Include the type of reaction, the products that form, and any conditions required. Mechanisms for the reactions are **not** required.

(6)

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(Total for Question 5 = 6 marks)

6 An ester **Q** has the molecular formula $C_8H_{16}O_2$.

(a) When burned in excess oxygen, 1.879 g of **Q** formed 4.594 g of carbon dioxide and 1.879 g of water.

Show that the empirical formula of **Q** is C_4H_8O.

(4)

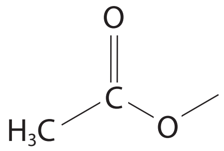
(b) Data from the high resolution ^{1}H (proton) NMR spectrum of the ester **Q** are shown in the table.

Chemical shift (δ) / ppm	Splitting pattern of peak	Relative peak area
2.50	singlet	3
1.56	quartet	4
1.43	singlet	3
0.92	triplet	6

Part of the structure of **Q** is shown.

Complete the structure of **Q**.
Justify your answer by linking the proton environments in your structure to the relative peak areas and the splitting pattern of the peaks.

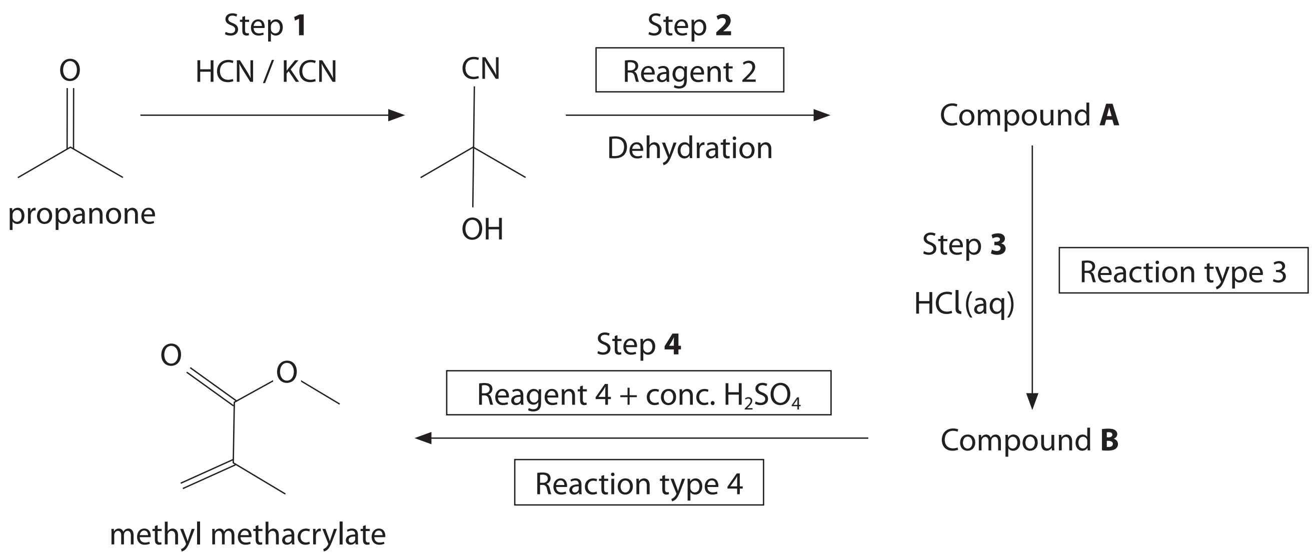
(7)



(Total for Question 6 = 11 marks)

7 This question is about some reactions of carbonyl compounds.

(a) Methyl methacrylate is the monomer used to make the polymer perspex.
It can be synthesised from propanone using the reaction scheme shown.



(i) Draw the mechanism for the reaction in Step **1**.
Include curly arrows and any relevant lone pairs and dipoles.

(4)

(ii) Complete the table to show the information missing from the reaction scheme.

(6)

Reagent 2	
Structure of compound **A**	
Reaction type 3	
Structure of compound **B**	
Reagent 4	
Reaction type 4	

(iii) Complete the equation for the formation of the polymer from methyl methacrylate.

(2)

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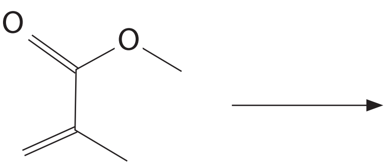

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(b) Propanone can be formed from the fermentation of polysaccharides such as starch. The propanone can be separated from the fermentation mixture by distillation.

Draw the apparatus used in the laboratory for distillation of propanone from the reaction mixture.

(3)

(c) Carbonyl compounds, such as propanone, react with 2,4-dinitrophenylhydrazine in solution (Brady's reagent) to form a precipitate which can be used to identify the compound.

The precipitate can be purified by recrystallisation.

Details of the recrystallisation process are shown.

Step **1** Dissolve the precipitate in the minimum volume of hot ethanol.

Step **2** Warm a filter paper and funnel in an oven for use in Step **3**.

Step **3** Filter the solution whilst still warm to remove any undissolved solids, using gravity filtration.

Step **4** Allow the filtrate to cool and recrystallise.

Step **5** Filter the crystals under reduced pressure.

Step **6** Rinse the crystals with a small amount of ice-cold ethanol.

Step **7** Dry the crystals between filter papers and leave in a desiccator.

(i) Explain why the filter paper and funnel are warmed in an oven before Step **3**.

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(ii) Explain how Steps **4** and **5** remove impurities from the crystalline product.

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(iii) State how the purified crystals can be used to identify the carbonyl compound that reacts with 2,4-dinitrophenylhydrazine.

Detailed descriptions of practical procedures are not required.

(2)

(Total for Question 7 = 21 marks)

8 This question is about acids and bases.

(a) Devise an experiment to determine the acid dissociation constant, K_a, for a solution of ethanoic acid, CH_3COOH, of unknown concentration.

Assume you have access to a pH meter and a solution of sodium hydroxide of similar concentration to the acid.
Include how to determine K_a from your results.

(5)

(b) 500 cm^3 of a buffer solution of pH = 4.70 is required.

Calculate the volume of 0.800 mol dm^{-3} sodium ethanoate solution and of 0.800 mol dm^{-3} ethanoic acid needed to make this buffer.

[K_a for ethanoic acid = 1.74×10^{-5} mol dm^{-3}]

(3)

(c) Calculate the pH of the solution formed when $51.2\,cm^3$ of $0.927\,mol\,dm^{-3}$ NaOH(aq) is mixed with $40.4\,cm^3$ of $0.370\,mol\,dm^{-3}$ H_2SO_4(aq).

[Ionic product of water $K_w = 1.00 \times 10^{-14}\,mol^2\,dm^{-6}$]

(6)

(Total for Question 8 = 14 marks)

9 Pineapple juice contains the weak acids citric acid ($C_6H_8O_7$) and ascorbic acid ($C_6H_8O_6$). The amount of each compound in a sample of 150 cm^3 of pineapple juice can be determined by titration.

(a) Experiment **1** is designed to determine the total amount of acid. 10.0 cm^3 samples of pineapple juice are transferred to separate conical flasks and titrated with a solution of sodium hydroxide of known concentration.

The total amount of acid in the 150 cm^3 sample of pineapple juice is 8.00×10^{-3} mol.

(i) Give a reason why methyl orange would **not** be a suitable indicator to use in this titration.

(1)

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(ii) A student did not notice an air bubble in the tip of the burette **before** carrying out one of their accurate titrations. During this titration, the air bubble escaped.

Explain the effect this mistake would have on the value of this titre.

(2)

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(b) Experiment **2** is carried out to determine the amount of ascorbic acid ($C_6H_8O_6$) in the pineapple juice.

An outline procedure for this experiment is given.

Step **1** 5.00 cm^3 of the pineapple juice is added to a conical flask.

Step **2** Deionised water, a small amount of HCl(aq), a few crystals of potassium iodide, KI, and 3 drops of starch solution are also added to the flask.

Step **3** The contents of the flask are swirled to ensure the KI dissolves fully.

Step **4** The resultant mixture is titrated with a solution of potassium iodate(V), KIO_3(aq), of concentration 0.00100 mol dm^{-3}.

The reactions that take place are

$$IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$$

$$C_6H_8O_6(aq) + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2I^-(aq)$$

Only the ascorbic acid reacts with the iodine.

(i) The end-point of the titration is when the starch changes colour.

Explain how this occurs, including the colour change.

(3)

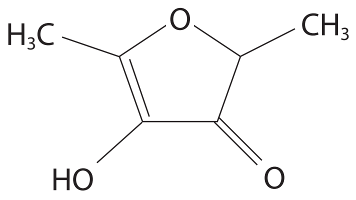
(ii) The **total** amount of acid in the 150 cm^3 sample is 8.00×10^{-3} mol.

The mean titre in Experiment **2** using 5.00 cm^3 of pineapple juice is 9.50 cm^3.

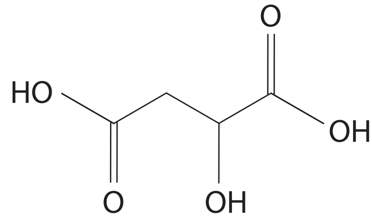
Calculate the mass of **citric acid** in the 150 cm^3 sample.

(5)

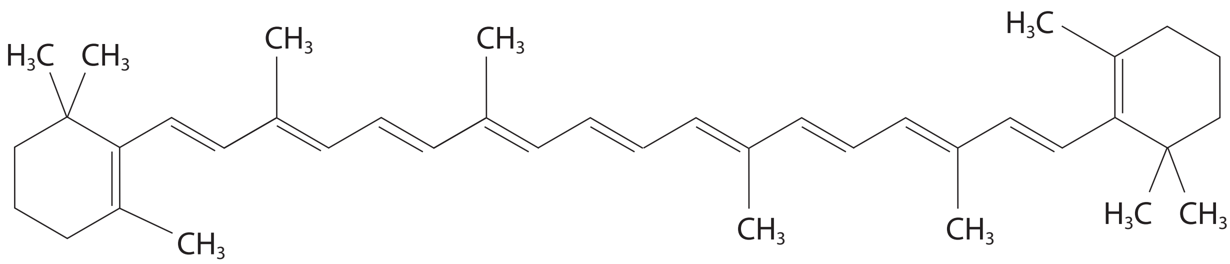
(c) While doing background research for the experiment, a student found that three other compounds, **D**, **E** and **F**, are often present in pineapple juice.



Compound **D**



Compound **E**



Compound **F**

Predict which one of these compounds is most likely to affect the result of Experiment **1** and hence predict the effect on the mass of citric acid calculated in (b)(ii).
Justify your answer.

(3)

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(Total for Question 9 = 14 marks)

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Turn over

10 The progress of the reaction between iodine and propanone with an acid catalyst can be followed in an experiment using a titrimetric method.

Procedure

Step **1** Mix 25 cm^3 of 1 mol dm^{-3} aqueous propanone with 25 cm^3 of 1 mol dm^{-3} sulfuric acid in a beaker. Both these reactants are in excess.

Step **2** Start the stop clock as 50 cm^3 of 0.02 mol dm^{-3} iodine solution is added to the beaker. Mix the reactants thoroughly.

Step **3** Withdraw a 10.0 cm^3 sample of the reaction mixture, using a pipette, and transfer it to a conical flask.

Step **4** Add a spatula measure of sodium hydrogencarbonate, noting the exact time.

Step **5** Titrate the iodine present in the 10.0 cm^3 sample with 0.01 mol dm^{-3} sodium thiosulfate solution, using starch indicator.

Step **6** Continue to withdraw 10.0 cm^3 samples about every two minutes, repeating Steps **4** and **5** with each sample.

(a) (i) Explain why sodium hydrogencarbonate is added in Step **4**.

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(ii) Write the **ionic** equation for the reaction that takes place during Step **4**. State symbols are not required.

(1)

(b) Some data from the experiment are shown.

Time sodium hydrogencarbonate is added / min	2.0	5.0	6.5	8.0	10.5	12.0
Volume of sodium thiosulfate / cm^3	19.2	15.5	14.0	12.1	9.5	7.2

(i) Plot a graph of the volume of sodium thiosulfate against the time the sodium hydrogencarbonate is added.

(2)

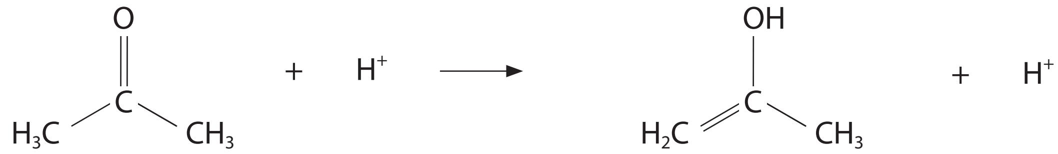
(ii) Explain how the graph of volume of thiosulfate against time confirms the reaction is zero order with respect to iodine, I_2.

(3)

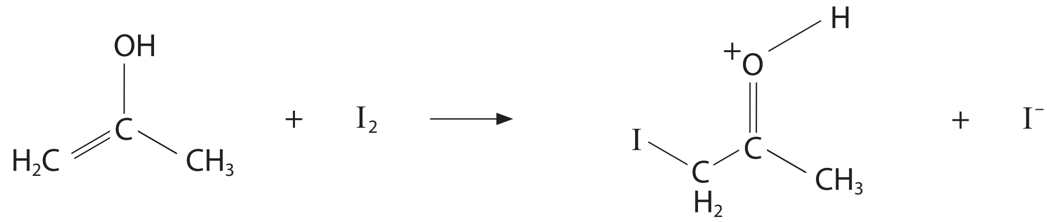
(c) The overall rate equation for the reaction is rate = $k[H^+(aq)][CH_3COCH_3(aq)]$.

A student researching the mechanism for the reaction found this example.

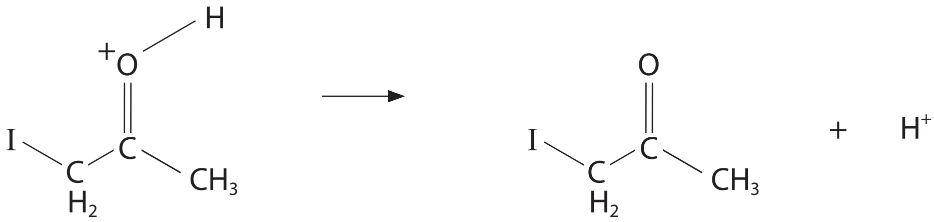
Step **1**



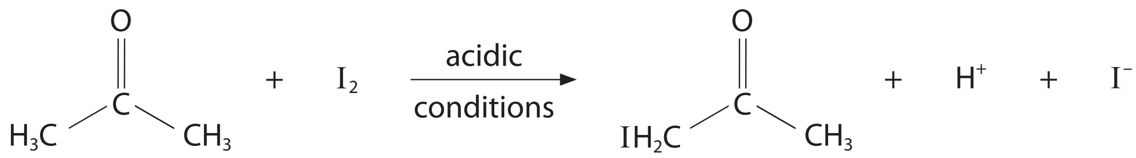
Step **2**



Step **3**



Overall reaction



(i) Predict which of the three steps is the rate-determining step.
Justify your answer.

(2)

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(ii) The student stated that

'The hydrogen ions cannot be acting as a catalyst.
One hydrogen ion is a reactant in Step **1** but two hydrogen ions are formed as products in Steps **1** and **3**.'

Explain whether or not this statement is valid.

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(Total for Question 10 = 12 marks)

TOTAL FOR PAPER = 120 MARKS

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The Periodic Table of Elements

Key

relative atomic mass **atomic symbol** name atomic (proton) number

1	2											3	4	5	6	7	0 (8)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
							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** 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	95.9 **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	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103