

Subject: Chemistry

Mark
/ 100

This paper has two parts of questions and an appendix. Part 1 consists of multiple choice questions, while Part 2 is composed of short answer questions. The appendix provides some useful information and data if you need.

Part 1. Multiple Choice [20 marks]

Choose a best option (A, B or C) and write it in front of the question number.

- Which is a homogeneous mixture?
A. Oil and water B. Sand and water C. Ethanol and water D. Chalk and sand
- What are the strongest intermolecular forces between molecules of propanone, CH_3COCH_3 , in the liquid phase?
A. London (dispersion) forces B. Covalent bonding C. Hydrogen bonding D. Dipole–dipole forces
- Which change increases the rate of formation of hydrogen when zinc reacts with excess hydrochloric acid, assuming all other conditions remain the same?
A. Adding water to the hydrochloric acid
B. Decreasing the temperature
C. Increasing the volume of hydrochloric acid
D. Decreasing the size of the zinc particles while keeping the total mass of zinc the same
- What is the molecular formula of a hydrocarbon containing 84.6% carbon by mass with a molar mass of 142.3 g mol^{-1} ?
A. $\text{C}_{20}\text{H}_{44}$ B. $\text{C}_{11}\text{H}_{10}$ C. $\text{C}_{10}\text{H}_{22}$ D. C_5H_{11}
- Which statements are correct?
I. The activation energy of a reaction is not affected by temperature.
II. A catalyst reduces the enthalpy change of a reaction.
III. Catalysts provide alternative reaction pathways.
A. I and II only B. I and III only C. II and III only D. I, II and III
- What is the percentage yield when 7 g of ethene produces 6 g of ethanol? $M_r(\text{ethene}) = 28$ and $M_r(\text{ethanol}) = 46$
$$\text{C}_2\text{H}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightarrow \text{C}_2\text{H}_5\text{OH}(\text{g})$$

A. $\frac{6 \times 7 \times 100}{28 \times 46} \%$ B. $\frac{6 \times 46 \times 100}{7 \times 28} \%$ C. $\frac{6 \times 28}{7 \times 46 \times 100} \%$ D. $\frac{6 \times 28 \times 100}{7 \times 46} \%$

7. Which shows the number of subatomic particles in $^{31}\text{P}^{3-}$?

	Protons	Neutrons	Electrons
A.	15	16	18
B.	15	16	12
C.	16	31	15
D.	31	31	15

8. Which are correct statements about the emission spectrum of hydrogen in the visible region?

I. The red line has a lower energy than the blue line.

II. The lines converge at longer wavelength.

III. The frequency of the blue line is greater than the frequency of the red line.

A. I and II only B. I and III only C. II and III only D. I, II and III

9. Which statement is correct?

A. Atomic radius decreases down group 17.

B. First ionization energy decreases down group 1.

C. Atomic radius increases across period 3 from Na to Cl.

D. First ionization energy decreases across period 3 from Na to Cl.

10. Which species has the longest carbon to oxygen bond length?

A. CO B. CH_3OH C. CH_3CO_2^- D. H_2CO

11. The compounds shown below have similar relative molecular masses. What is the correct order of increasing boiling point?

A. $\text{CH}_3\text{COOH} < (\text{CH}_3)_2\text{CO} < (\text{CH}_3)_2\text{CHOH}$

B. $\text{CH}_3\text{COOH} < (\text{CH}_3)_2\text{CHOH} < (\text{CH}_3)_2\text{CO}$

C. $(\text{CH}_3)_2\text{CO} < \text{CH}_3\text{COOH} < (\text{CH}_3)_2\text{CHOH}$

D. $(\text{CH}_3)_2\text{CO} < (\text{CH}_3)_2\text{CHOH} < \text{CH}_3\text{COOH}$

12. Two 100 cm^3 aqueous solutions, one containing 0.010 mol NaOH and the other 0.010 mol HCl , are at the same temperature. When the two solutions are mixed the temperature rises by $y\text{ }^\circ\text{C}$. Assume the density of the final solution is 1.00 g cm^{-3} . Specific heat capacity of water = $4.18\text{ J g}^{-1}\text{ K}^{-1}$ What is the enthalpy change of neutralization in kJ mol^{-1} ?

A. $\frac{200 \times 4.18 \times y}{1000 \times 0.020}$

B. $\frac{200 \times 4.18 \times y}{1000 \times 0.010}$

C. $\frac{100 \times 4.18 \times y}{1000 \times 0.010}$

D. $\frac{200 \times 4.18 \times (y + 273)}{1000 \times 0.010}$

13. Which factors can affect the rate of reaction?

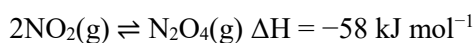
I. Particle size of solid reactant

II. Concentration of reacting solution

III. Pressure of reacting gas

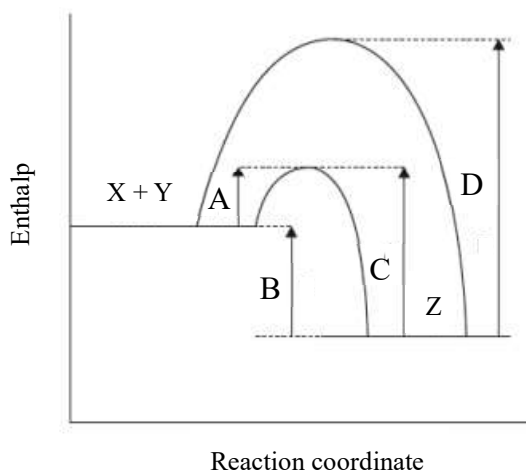
A. I and II only B. I and III only C. II and III only D. I, II and III

14. Which factor does not affect the position of equilibrium in this reaction?



- A. Change in volume of the container
- B. Change in temperature
- C. Addition of a catalyst
- D. Change in pressure

15. The potential energy profile for the reversible reaction, $\text{X} + \text{Y} \rightleftharpoons \text{Z}$ is shown.



Which arrow represents the activation energy for the reverse reaction, $\text{Z} \rightarrow \text{X} + \text{Y}$, with a catalyst?

16. Activity series of selected elements:

K, Ca, Al, Fe, H, Cu, Ag, Au

greatest activity \longleftrightarrow

least activity

Which react with dilute sulfuric acid?

- I. Cu
- II. CuO
- III. CuCO_3

- A. I and II only B. I and III only C. II and III only D. I, II and III

17. Which statement is correct?

- A. A strong acid is a good proton donor and has a strong conjugate base.
- B. A weak acid is a poor proton acceptor and has a strong conjugate base.
- C. A strong acid is a good proton donor and has a weak conjugate base.
- D. A strong base is a good proton donor and has a weak conjugate acid.

18. What is the volume, in cm^3 , of the final solution if 100 cm^3 of a solution containing 1.42 g of sodium sulfate, Na_2SO_4 , is diluted to the concentration of $0.020 \text{ mol dm}^{-3}$? $M_r(\text{Na}_2\text{SO}_4) = 142$

- A. 50 B. 400 C. 500 D. 600

19. Which increase across a period from left to right?

A.	ionic radius	electronegativity
B.	atomic radius	ionic radius
C.	1 st ionization energy	atomic radius
D.	1 st ionization energy	electronegativity

20. What is the formula of magnesium nitride?

- A. MgN B. Mg₂N₃ C. Mg₃N D. Mg₃N₂

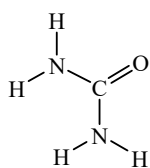
Part 2. Short Answer [80 marks]

Using Mandarin to answer the short questions is allowed except question 32 and 33.

21. Urea, (H₂N)₂CO, is excreted by mammals and can be used as a fertilizer.

21a. Calculate the percentage by mass of nitrogen in urea to two decimal places using the data in the appendix. [1 marks]

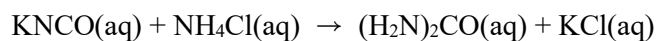
21b. The structural formula of urea is shown.



Predict the electron domain and molecular geometries at the nitrogen and carbon atoms, applying the VSEPR theory. [3 marks]

Element	Electron domain geometry	Molecular geometry
Carbon		
Nitrogen		trigonal planar

21c. Urea can be made by reacting potassium cyanate, KNCO , with ammonium chloride, NH_4Cl .



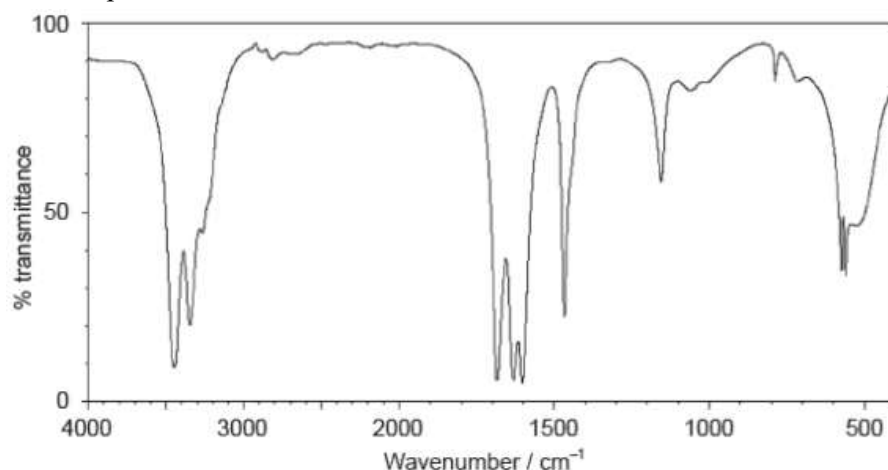
Determine the maximum mass of urea that could be formed from 50.0 cm of 0.100 mol dm^{-3} potassium cyanate solution. [1 marks]

21d. Sketch two different hydrogen bonding interactions between ammonia and water. [2 marks]

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21e. The combustion of urea produces water, carbon dioxide and nitrogen. Formulate a balanced equation for the reaction. [2 marks]

21f. The IR spectrum of urea is shown below.



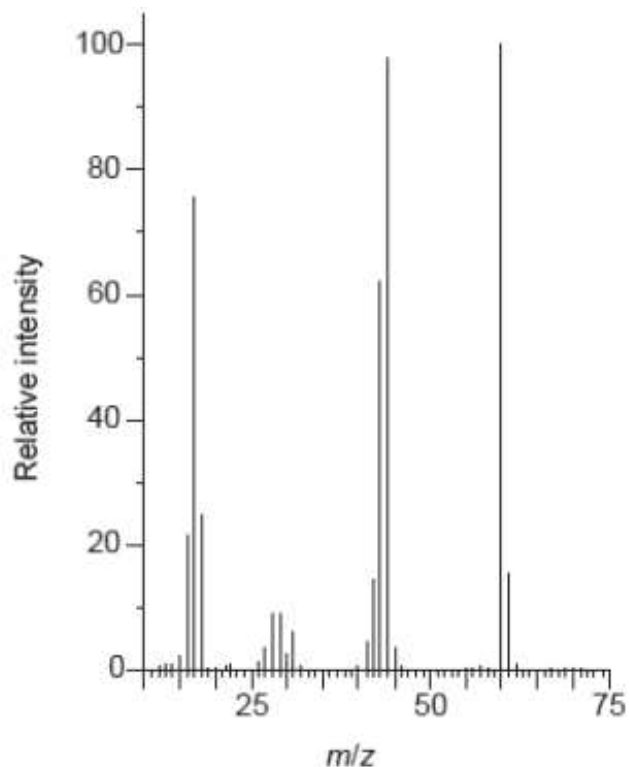
[Source: SDBS, National Institute of Advanced Industrial Science and Technology]

Identify the bonds causing the absorptions at 3450 cm^{-1} and 1700 cm^{-1} using the data in the appendix. [2 marks]

3450 cm⁻¹:

1700 cm⁻¹:

21g. The mass spectrum of urea is shown below.



[Source: NIST Mass Spec Data Center, S.E. Stein, director, "Mass Spectra" in *NIST Chemistry WebBook*, NIST Standard Reference Database Number 69, Eds. P.J. Linstrom and W.G. Mallard, National Institute of Standards and Technology, Gaithersburg MD, 20899, doi:10.18434/T4D303, (retrieved May 31, 2018).]

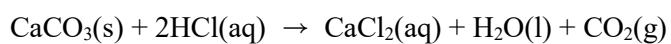
Identify the species responsible for the peaks at the mass/charge ratio (m/z) equal to 60 and 44. [2 marks]

60:

44:

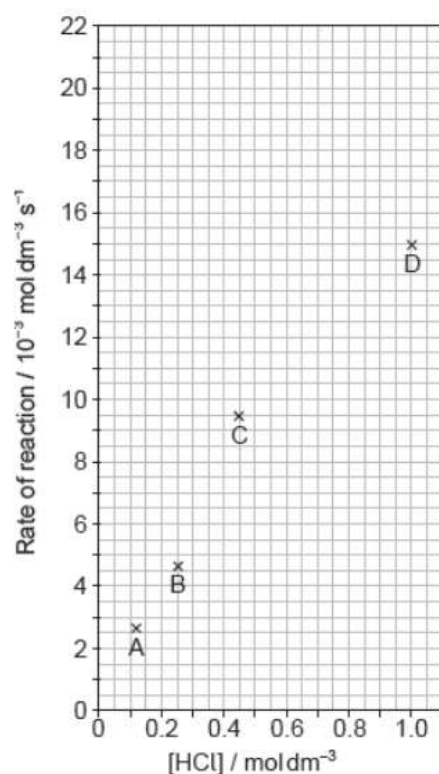
21h. Predict the number of signals in the ¹H NMR spectrum of urea. [1 marks]

22. Calcium carbonate reacts with hydrochloric acid.



22a. Outline two ways in which the progress of the reaction can be monitored. No practical details are required. [2 marks]

22b. The results of a series of experiments in which the concentration of HCl was varied are shown below.



Suggest why point D is so far out of line assuming human error is not the cause. [1 mark]

22c. Suggest the relationship that points A, B and C (in 22b) show between the concentration of the acid and the rate of reaction. [1 mark]

23. A student determined the percentage of the active ingredient magnesium hydroxide, $\text{Mg}(\text{OH})_2$, in a 1.24 g antacid tablet.

23a. The antacid tablet was added to 50.00 cm^3 of $0.100 \text{ mol dm}^{-3}$ sulfuric acid, which was in excess. Calculate the amount, in mol, of H_2SO_4 . [1 mark]

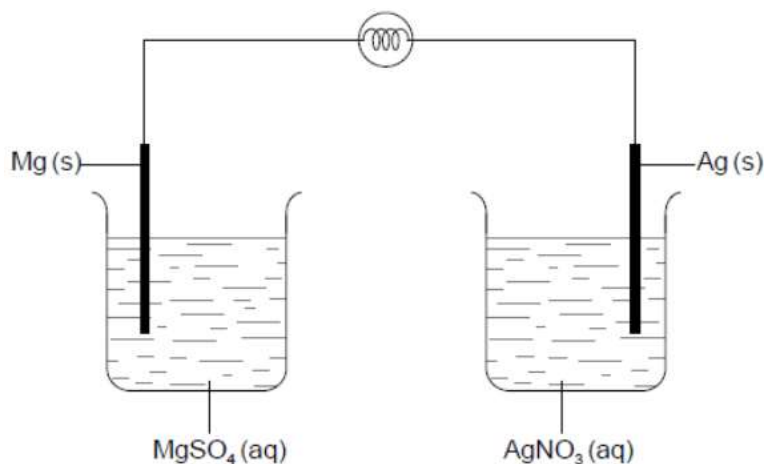
23b. The excess sulfuric acid required 20.80 cm^3 of $0.1133 \text{ mol dm}^{-3}$ NaOH for neutralization. Calculate the amount of excess acid present. [1 mark]

23c. Calculate the amount of H_2SO_4 that reacted with $\text{Mg}(\text{OH})_2$. [1 mark]

23d. Determine the mass of $\text{Mg}(\text{OH})_2$ in the antacid tablet. [1 marks]

23e. Calculate the percentage by mass of magnesium hydroxide in the 1.24 g antacid tablet to three significant figures. [1 mark]

24. The diagram shows an incomplete voltaic cell with a light bulb in the circuit.



24a. Identify the missing component of the cell and its function. [2 marks]

24b. Deduce the half-equations for the reaction at each electrode when current flows. [2 marks]

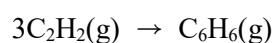
Positive electrode (cathode):
Negative electrode (anode):

25. This question is about ethene, C₂H₄, and ethyne, C₂H₂.

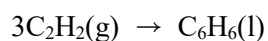
25a. Ethyne, like ethene, undergoes hydrogenation to form ethane. State the conditions required. [2 marks]

25b. Outline the formation of polyethene from ethene by drawing three repeating units of the polymer. [1 mark]

25c. Under certain conditions, ethyne can be converted to benzene. Determine the standard enthalpy change, ΔH^\ominus , for the reaction stated, using the data in the appendix. [2 marks]

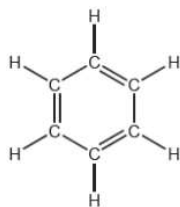


25d. Determine the standard enthalpy change, ΔH^\ominus , for the following similar reaction, using ΔH_f values in the appendix. [2 marks]



25e. Explain, giving two reasons, the difference in the values for 25c and 25d. If you did not obtain answers, use -475 kJ for 25c and -600 kJ for 25d. [1 marks]

25f. One possible Lewis structure for benzene is shown.



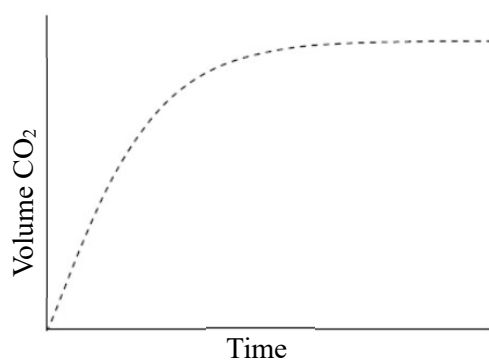
State one piece of physical evidence that this structure is incorrect. [1 mark]

26. Graphing is an important tool in the study of rates of chemical reactions.

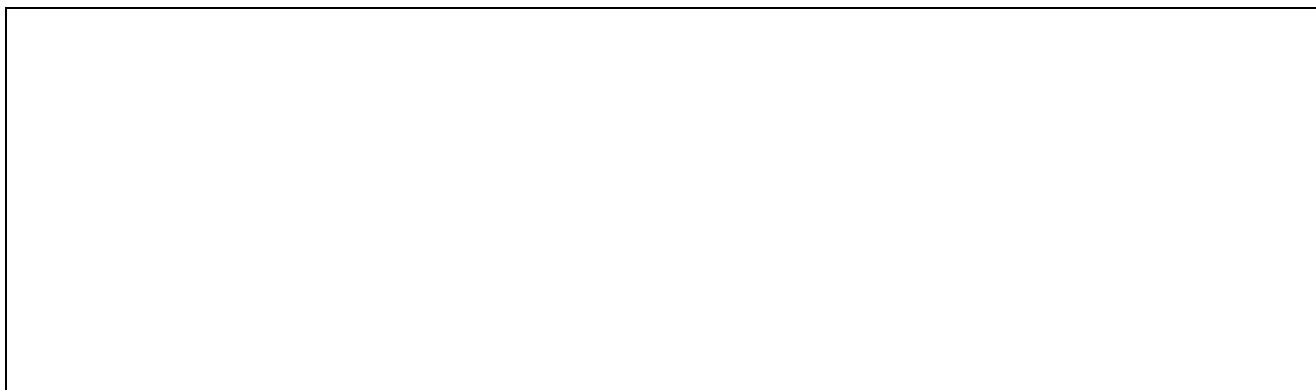
26a. Sketch a Maxwell–Boltzmann distribution curve for a chemical reaction showing the activation energies with and without a catalyst. [3 marks]

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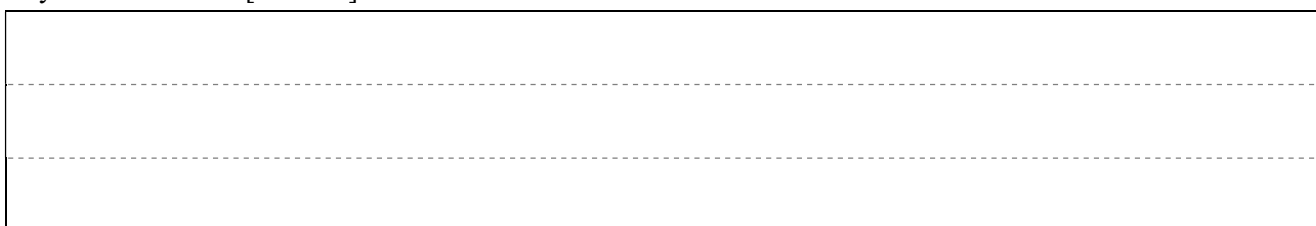
26b. Excess hydrochloric acid is added to lumps of calcium carbonate. The graph shows the volume of carbon dioxide gas produced over time.



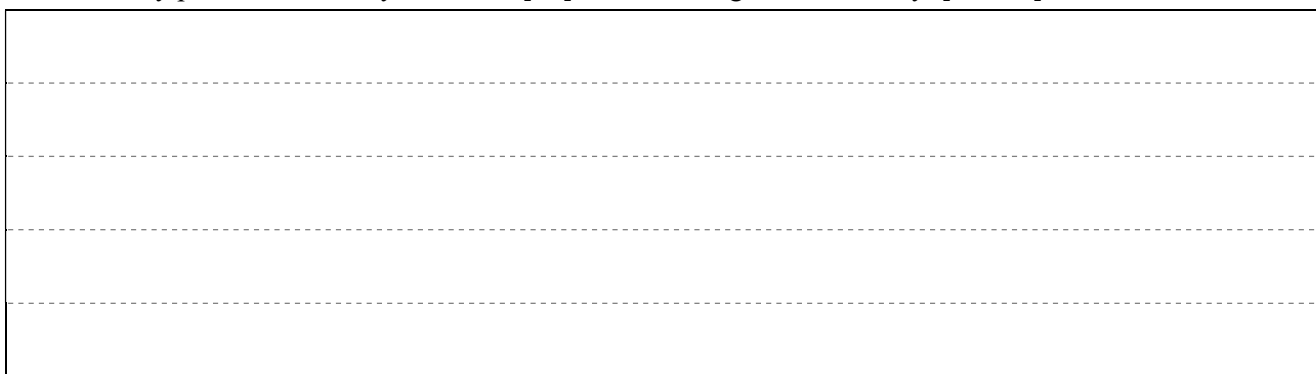
Sketch a curve on the graph to show the volume of gas produced over time if the same mass of crushed calcium carbonate is used instead of lumps. All other conditions remain constant. [1 mark]



26c. State and explain the effect on the rate of reaction if ethanoic acid of the same concentration is used in place of hydrochloric acid. [2 marks]

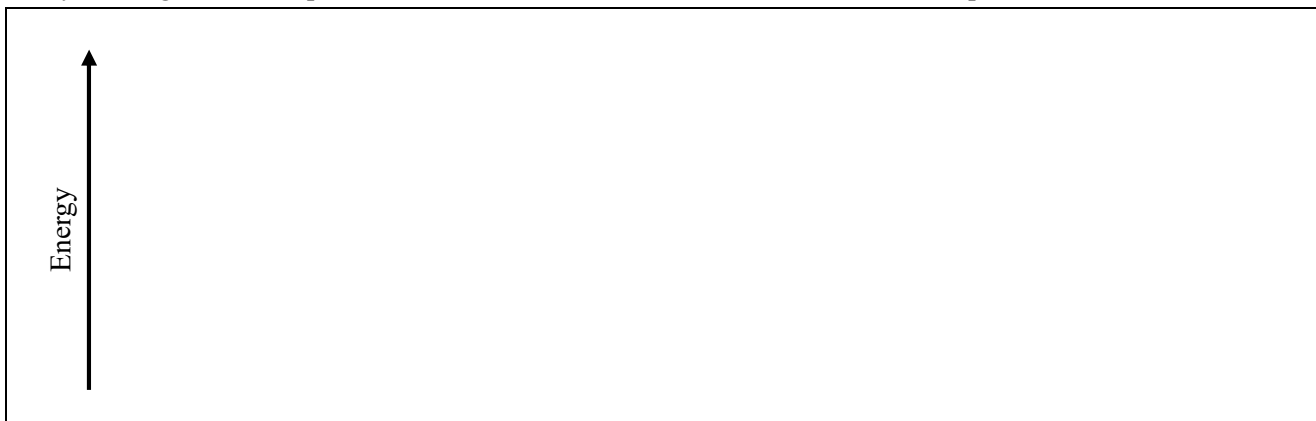


26d. Outline why pH is more widely used than $[H^+]$ for measuring relative acidity. [1 mark]



27. The emission spectrum of an element can be used to identify it.

27a. Draw the first four energy levels of a hydrogen atom on the axis, labelling $n = 1, 2, 3$ and 4 . Draw the arrows, on your diagram, that represent the electron transitions to $n = 2$ in the emission spectrum. [2 marks]



27b. Elements show trends in their physical properties across the periodic table. Outline why atomic radius decreases across period 3, sodium to chlorine. [1 mark]

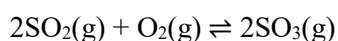
27c. Outline why the ionic radius of K^+ is smaller than that of Cl^- . [2 marks]

27d. Copper is widely used as an electrical conductor. Draw arrows in the boxes to represent the electronic configuration of copper in the 4s and 3d orbitals. [1 mark]

27e. Impure copper can be purified by electrolysis. In the electrolytic cell, impure copper is the anode (positive electrode), pure copper is the cathode (negative electrode) and the electrolyte is copper(II) sulfate solution. Formulate the half-equation at each electrode. [2 marks]

Positive electrode (anode):
Negative electrode (cathode):

28. A mixture of 1.00 mol $SO_2(g)$, 2.00 mol $O_2(g)$ and 1.00 mol $SO_3(g)$ is placed in a 1.00 dm³ container and allowed to reach equilibrium.



28a. Distinguish between the terms reaction quotient, Q , and equilibrium constant, K_C . [1 mark]

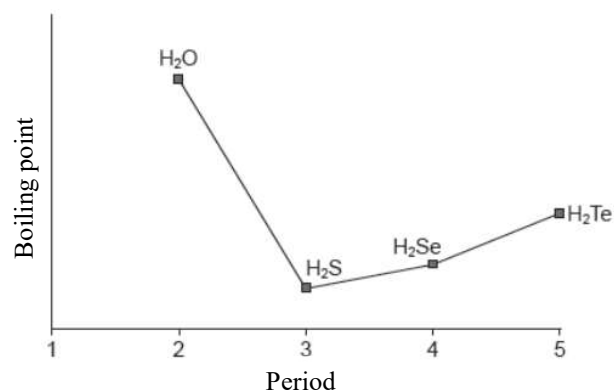
28b. The equilibrium constant, K_C , is 0.282 at temperature T. Deduce, showing your work, the direction of the initial reaction. [2 marks]

29. Some physical properties of molecular substances result from the different types of forces between their molecules.

29a. Explain why the hydrides of group 16 elements (H_2O , H_2S , H_2Se and H_2Te) are polar molecules. [2 marks]

29b. The graph shows the boiling points of the hydrides of group 16 elements.

Explain the increase in the boiling point from H_2S to H_2Te . [2 marks]



30. The questions from 30a to 30c share the same conditions. In the experiment of determining molecular mass of carbon dioxide, CO_2 , the ideal gas equation, $PV = nRT$, is employed to calculate the molecular mass, g mol^{-1} . The equipment of preparation of CO_2 is shown as figure 1. Table 1 shows the data of the experiment results, the temperature, the pressure, the mass of the syringe with the rubber bung, and the mass of the syringe with the bung containing carbon dioxide. The volume of the syringe is 60.0 cm^3 .

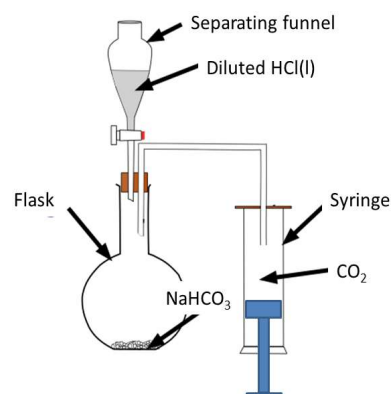


Figure 1

Table 1. The data of the experiment to determine M_r of CO_2 .

No.	mass (syringe + bung)/g	mass (syringe + bung + CO_2)/g	mass CO_2 /g
1	26.524	26.563	
2	26.521	26.559	(IV)
3	26.522	26.562	

temperature = $27.0\text{ }^\circ\text{C}$, atmospheric pressure = $1.01 \times 10^5\text{ N m}^{-2}$

30a. According to the data of No.2 in table 1, determine the mass of CO_2 , i.e. (IV), in g. [1 mark]

30b. According to the data of No.2 in table 1, determine the molecular mass, in g mol^{-1} , using the ideal gas equation. [2 marks]

30c. The molecular mass determined by the ideal gas equation is quite different from the molecular mass of CO_2 , 44 g mol^{-1} . Explain the reason that causes the difference. [1 marks]

31. The questions from 31a to 31d share the same conditions. The experiment of determining the chemical formula of magnesium oxide.

31a. The reaction in (a) was carried out in a crucible with a lid and the following data was recorded. Calculate the amount of magnesium, in mol, that was used. [1 mark]

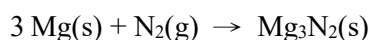
Mass of crucible and lid = $47.372 \pm 0.001\text{ g}$

Mass of crucible, lid and magnesium ribbon before heating = $53.726 \pm 0.001\text{ g}$

Mass of crucible, lid and product after heating = $56.941 \pm 0.001\text{ g}$

31b. Assume the reaction in (a) is the only one occurring and it goes to completion, but some product has been lost from the crucible. Deduce the percentage yield of magnesium oxide in the crucible. [1 mark]

31c. When magnesium is burnt in air, some of it reacts with nitrogen to form magnesium nitride according to the equation:



Evaluate whether this, rather than the loss of product, could explain the yield found in (c). [1 mark]

32. Read the following texts about the development of the periodic table.

The Periodic Table, a vital tool to predict the way elements react, is a method of categorizing elements according to their properties. Scientists started to look for a way to categorize the known elements around 200 years ago. In 1817, Johann Döbereiner noticed that the atomic mass of Sr fell midway between the weights of Ca and Ba. These were elements which possessed similar chemical properties. They formed a triad of elements. Other triads were also discovered, composed of:

Cl, Br, I, and Li, Na, K.

He called this the ‘Law of Triads’.

In 1865, John Newlands, an English chemist, arranged the 56 known elements in order of increasing atomic mass. He found every eighth element in the series was similar:

H **Li** Be B C N O F **Na** Mg Al Si P S Cl **K**

He likened this to music and called it the ‘Law of Octaves’.

In 1869, the Russian Dmitri Mendeleev arranged all the 63 known elements in order of increasing atomic mass but in such a way that elements with similar properties were in the same vertical column. If necessary, he left gaps in the table. Mendeleev's periodic table was tested by making predictions about elements that were unknown at that time but could possibly fill the gaps. As new elements were discovered, they were found to fit easily into the classification. For example, Mendeleev predicted the properties of the missing element 'eka-silicon' with the color, density and melting point as well as its atomic mass. In 1886 the element germanium was discovered in Germany by Clemens Winkler; its properties were almost exactly those Mendeleev had predicted. In all, Mendeleev predicted the atomic mass of ten new elements, of which seven were eventually discovered. His periodic table was quickly accepted by scientists as an important summary of the properties of the elements.

32a. Use the verbs (with correct form) in the box below to complete the following summary of the texts.

[7 marks]

arrange	begin	categorize	discover	increase	predict	react
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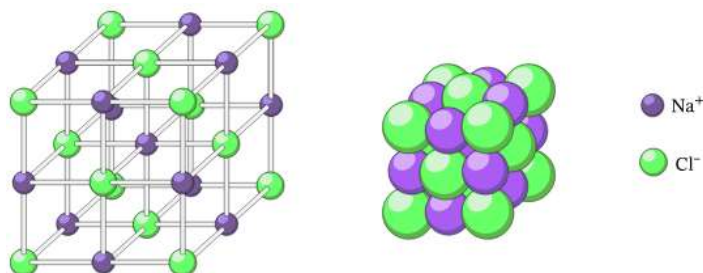
Summary

The Periodic Table (1) elements based on their properties and is crucial in predicting how they (2). Scientists (3) looking for a way to organize elements two centuries ago. Johann Döbereiner (4) triads of elements with similar properties, while John Newlands found that every eighth element was similar. Dmitri Mendeleev (5) all known elements in order of (6) atomic mass and left gaps where necessary, (7) properties of unknown elements. His predictions were validated when new elements were discovered. Mendeleev's periodic table was quickly accepted as a summary of element properties.

(1)		(2)		(3)		(4)	
(5)		(6)		(7)			

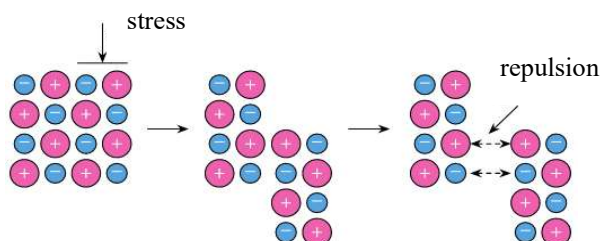
33. The article below describes the ionic compound and its properties. Read the article and underline some key words of the properties.

In an ionic compound, the ions are packed together in a regular arrangement called a lattice. Within the lattice, oppositely charged ions attract one another strongly. The Figure below shows a tiny part of the crystal of sodium chloride. Many trillions of sodium ions and chloride ions would be arranged in this way in the crystal make up the giant ionic structure. Each sodium ion in the lattice is surrounded by six chloride ions, and each chloride ion is surrounded by six sodium ions.



Due to the strong electrostatic forces holding the crystal lattice together, a lot of energy is needed to separate the ions. There ionic compounds have the following properties.

- They are usually solids at room temperature, with high melting points
- They are usually hard substances but brittle due to lack of ductility, see figure below.
- They cannot conduct electricity when solid, because the ions are not free to move in the solid state. However, in the molten state and in aqueous solution, they conduct electricity.
- They mainly dissolve in water. This is because water molecules are able to bond with both the cations and anions, which breaks up the lattice and keeps the ions apart.



33a. According to the article of the ionic compound and its properties, finish the cross-words puzzle.

[8 marks]

						7					across
1											1 cause to move or be apart
											2 arranged in or constituting a constant or definite pattern
2		5		6							3 very small
											4 cause to separate into pieces
											down
									8		1 be all around (someone or something)
						3					5 of very great size or force
											6 a regular repeated three-dimensional arrangement of atoms, ions, or molecules in a metal or other crystalline solid
											7 cause to come to a place or participate in a venture by offering something of interest or advantage
		4									8 a negatively charged ion

1. Periodic Table

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2. Infrared Data

Characteristic ranges for infrared absorption due to stretching vibrations in organic molecules.

Bond	Organic molecules	Wavenumber (cm^{-1})	Intensity
C-I	iodoalkanes	490–620	strong
C-Br	bromoalkanes	500–600	strong
C-Cl	chloroalkanes	600–800	strong
C-F	fluoroalkanes	1000–1400	strong
C-O	alcohols, esters, ethers	1050–1410	strong
C=C	alkenes	1620–1680	medium-weak; multiple bands
C=O	aldehydes, ketones, carboxylic acids and esters	1700–1750	strong
C \equiv C	alkynes	2100–2260	variable
O-H	hydrogen bonding in carboxylic acids	2500–3000	strong, very broad
C-H	alkanes, alkenes, arenes	2850–3090	strong
O-H	hydrogen bonding in alcohols and phenols	3200–3600	strong, broad
N-H	primary amines	3300–3500	medium, two bands

3. Bond enthalpies and average bond enthalpies at 298 K

Single bonds (kJ mol^{-1})

	Br	C	Cl	F	H	I	N	O	P	S	Si
Br	193	285	219	249	366	178		201	264	218	330
C	285	346	324	492	414	228	286	358	264	289	307
Cl	219	324	242	255	431	211	192	206	322	271	400
F	249	492	255	159	567	280	278	191	490	327	597
H	366	414	431	567	436	298	391	463	322	364	323
I	178	228	211	280	298	151		201	184		234
N		286	192	278	391		158	214			
O	201	358	206	191	463	201	214	144	363		466
P	264	264	322	490	322	184		363	198		
S	218	289	271	327	364					266	293
Si	330	307	400	597	323	234		466		293	226

Multiple bonds (kJ mol^{-1})

C=C 614	C \equiv N 890	N \equiv N 945
C \equiv C 839	C=O 804	N=O 587
C=C (in benzene) 507	C=S 536	O=O 498
C=N 615	N=N 470	S=S 429

4. Selected compounds—thermodynamic data

Substance	Formula	State	ΔH_f° (kJ mol ⁻¹)	ΔG_f° (kJ mol ⁻¹)	S° (J K ⁻¹ mol ⁻¹)
methane	CH ₄	g	-74.0	-50.0	+186
ethane	C ₂ H ₆	g	-84.0	-32.0	+230
propane	C ₃ H ₈	g	-105	-24.0	+270
butane	C ₄ H ₁₀	g	-126	-17.0	+310
pentane	C ₅ H ₁₂	l	-173		
hexane	C ₆ H ₁₄	l	-199		
ethene	C ₂ H ₄	g	+52.0	+68.0	+220
propene	C ₃ H ₆	g	+20.0	+62.0	+267
but-1-ene	C ₄ H ₈	g	+0.10	+71.0	+306
<i>cis</i> -but-2-ene	C ₄ H ₈	g	-7.0	+66.0	+301
<i>trans</i> -but-2-ene	C ₄ H ₈	g	-11.0	+63.0	+297
ethyne	C ₂ H ₂	g	+228	+211	+201
propyne	C ₃ H ₄	g	+185	+194	+248
buta-1,3-diene	C ₄ H ₆	g	+110	+151	+279
cyclohexane	C ₆ H ₁₂	l	-156		
benzene	C ₆ H ₆	l	+49.0	+125	+173
methylbenzene	C ₆ H ₅ CH ₃	l	+12.0		
ethylbenzene	C ₆ H ₅ CH ₂ CH ₃	l	-12.0		
phenylethene	C ₆ H ₅ CHCH ₂	l	+104		
chloromethane	CH ₃ Cl	g	-82.0	-58.0	+235
dichloromethane	CH ₂ Cl ₂	l	-124		+178
trichloromethane	CHCl ₃	l	-134	-74.0	+202
bromomethane	CH ₃ Br	g	-36.0	-26.0	+246
iodomethane	CH ₃ I	l	-14.0		+163
chloroethane	C ₂ H ₅ Cl	g	-137	-53.0	
bromoethane	C ₂ H ₅ Br	l	-90.0	-26.0	+199
chlorobenzene	C ₆ H ₅ Cl	l	+11.0		
methanol	CH ₃ OH	l	-239	-167	+127
ethanol	C ₂ H ₅ OH	l	-278	-175	+161
phenol	C ₆ H ₅ OH	s	-165		+144
methanal	HCHO	g	-109	-102	+219
ethanal	CH ₃ CHO	g	-166	-133	+264
propanone	(CH ₃) ₂ CO	l	-248		+200
methanoic acid	HCOOH	l	-425	-361	+129
ethanoic acid	CH ₃ COOH	l	-484	-390	+160
benzoic acid	C ₆ H ₅ COOH	s	-385		+168
methylamine	CH ₃ NH ₂	g	-23	+32.0	+243
water	H ₂ O	l	-285.8	-237.1	+70.0
steam	H ₂ O	g	-241.8	-228.6	+188.8
carbon monoxide	CO	g	-110.5	-137.2	+197.7
carbon dioxide	CO ₂	g	-393.5	-394.4	+213.8
hydrogen bromide	HBr	g	-36.3	-53.4	+198.7
hydrogen chloride	HCl	g	-92.3	-95.3	+186.9
hydrogen fluoride	HF	g	-273.3	-275.4	+173.8
hydrogen iodide	HI	g	+26.5	+1.7	+206.6