SECTION A – Multiple-choice questions

Instructions for Section A

Answer all questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1, an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No mark will be given if more than one answer is completed for any question.

Question 1

Which one of the following contains the least number of molecules?

A. 1 g CH_4

B. 1 g C_2H_6

C. 1 g C_3H_8

D. 1 g C_4H_{10}

Question 2

The number of ions in 0.50 mol of ammonium carbonate, $(NH_4)_2CO_3$ is closest to

A. 3.0×10^{23}

B. 4.5×10^{23}

C. 6.0×10^{23}

D. 9.0×10^{23}

Question 3

A sample of vinegar containing 0.100 mol of ethanoic acid, CH_3COOH, has a concentration of 0.125 mol L^{-1} of ethanoic acid. What is the volume of the solution?

A. 8.00 mL

B. 12.5 mL

C. 800 mL

D. 1.25 L

Question 4

If a sample of gas in a container of fixed volume is heated, which of the following will **not** occur?

A. The average speed of the molecules will increase.

B. The pressure exerted by the gas will increase.

C. The density of the gas will increase.

D. The average frequency of collisions with the walls will increase.

Question 5

Under which of the following conditions does a real gas behave least ideally?

A. Low pressure, low temperature

B. Low pressure, high temperature

C. High pressure, low temperature

D. High pressure, high temperature

Question 6

A flask of mass 80.0 g is filled with CO_2 ($M_r = 44$). Its total mass is now 82.2 g. If the CO_2 is replaced with CO ($M_r = 28$) under the same conditions, what will the total mass of the flask be?

A. 80.14 g

B. 81.4 g

C. 82.2 g

D. cannot be determined

Question 7

A vessel contains x molecules of O_2 (Mr = 32) at 50°C and 108 kPa. If the oxygen is removed and replaced by SO_2 ($M_r = 64$), how many SO_2 molecules will be pumped in at 50°C before the pressure returns to 108 kPa?

A. $0.5x$

B. x

C. $2x$

D. cannot be determined

Question 8

The sample of gas that would occupy the largest volume at SLC is

A. 1.0 g CH_4

B. 1.0 g O_2

C. 1.0 g CO_2

D. none of the above as all of the gases would occupy 24.5 L

Question 9

The Contact process for the synthesis of sulfuric acid involves several stages. A key reaction is the conversion of sulfur dioxide to sulfur trioxide according to the equation:

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

The maximum volume of sulfur trioxide, in litres, that can be prepared from 50 L of SO_2 and 50 L of O_2, **if all gases are measured at the same temperature and pressure**, is

A. 25

B. 50

C. 75

D. 100

Question 10

Which of the following would **not** be a source of carbon dioxide?

A. the burning of fossil fuels

B. fermentation of sugar to ethanol

C. the production of calcium oxide from calcium carbonate

D. photosynthesis

Question 11

The majority of the nitrogen found in the biosphere is present as

A. N_2

B. NO_3^-

C. NH_3

D. NO_2

Question 12

Which of the following is a weak, diprotic acid?

A. HCOOH

B. H_2SO_4

C. $(COOH)_2$

D. C_2H_2

Question 13

The following ions could act as bases. Which one has the least tendency to accept protons?

A. NO_3^-

B. NH_3

C. CO_3^{2-}

D. SO_3^{2-}

Question 14

The pH of a solution of 0.1 M Na_2HPO_4 (aq) was found to be 9.5. The **best** explanation of this is

A. The Na^+ ions form NaOH in solution.

B. Na_2HPO_4 is a proton acceptor.

C. The HPO_4^{2-} ions are ampholytes which preferentially donate protons to water molecules.

D. The HPO_4^{2-} ions are ampholytes which preferentially accept protons from water molecules.

Question 15

Which substance can be dissolved in water to give a 0.1 M solution with a high pH and a high electrical conductivity?

A. HCl

B. NaCl

C. NH3

D. NaOH

Question 16

The pH of solution **X** is 1 and that of **Y** is 2. Which statement is correct about the hydrogen ion concentrations in the two solutions?

A. $[H^+]$ in **X** is half that in **Y**.

B. $[H^+]$ in **X** is twice that in **Y**.

C. $[H^+]$ in **X** is one tenth that in **Y**.

D. $[H^+]$ in **X** is ten times that in **Y**.

Question 17

Carbon dioxide can be produced conveniently in the laboratory by

A. adding marble chips to hydrogen peroxide, H_2O_2, solution.

B. adding manganese dioxide powder to hydrogen peroxide solution.

C. strongly heating a sample of calcium carbonate.

D. adding calcium pieces to carbonic acid.

Question 18

In which of the following media would iron corrode at the greatest rate?

A. Distilled water

B. Tap water

C. Iced water

D. Carbonated tap water

Question 19

Which of the following pairs of substances when mixed, should react?

A. $Sn^{2+}(aq)$ and $Fe^{2+}(aq)$

B. $Ni^{2+}(aq)$ and $Sn^{2+}(aq)$

C. $Zn^{2+}(aq)$ and Fe (s)

D. Ni (s) and $Sn^{2+}(aq)$

Question 20

A simple way of detecting ozone in polluted air is to bubble the air through a potassium iodide solution. In a redox reaction, ozone oxidises colourless iodide ions to yellow-brown iodine. The correct equation for this reaction is

A. $2O_3(g) + 2I^-(aq) \rightarrow I_2(aq) + 3O_2(g)$

B. $O_3(g) + 2I^-(aq) + 3H^+(aq) \rightarrow I_2(aq) + 3OH^-(aq)$

C. $O_3(g) + 2I^-(aq) + 2H^+(aq) \rightarrow I_2(aq) + H_2O(l) + O_2(g)$

D. $O_3(g) + 2I^-(aq) + H_2O(l) \rightarrow I_2(aq) + 3OH^-(aq)$

END OF SECTION A

SECTION B – Short answer questions

Instructions for Section B

Answer **all** questions in the spaces provided.

To obtain full marks for your responses you should

- give simplified answers with an appropriate number of significant figures for all numerical questions; unsimplified answers will not be given full marks.
- show all working in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.
- make sure chemical equations are balanced and that the formulas for individual substances include an indication of state; for example, $H_2(g)$; NaCl(s)

Question 1

Consider the reaction: $MnO_2(s) + 4HCl(aq) \rightarrow MnCl_2(aq) + Cl_2(g) + 2H_2O(l)$

a. If 0.320 mol of MnO_2 and 48.2 g of HCl are reacted, which reagent is in excess and by what mass?

4 marks

b. How many grams of Cl_2 will be produced?

2 marks

Total 6 marks

Question 2

a. Dry ice is solid carbon dioxide. A 0.066 g sample of dry ice is placed in an evacuated 4.6 L vessel at 30°C.

Calculate the pressure, in kPa, inside the vessel after all the dry ice has been converted to CO_2 gas.

3 marks

b. Ozone molecules in the stratosphere absorb much of the harmful radiation from the sun. Typically, the temperature and pressure of ozone in the stratosphere are 250 K and 1.0×10^{-3} atm, respectively.

How many ozone molecules are present in 1.0 L of air under these conditions?

4 marks
Total 7 marks

Question 3

a. Draw structural formulae, without lone pairs, to represent both oxygen gas and ozone.

2 marks

b. Give **two** properties of oxygen and ozone that are distinctly different

_____

_____

2 marks

c. Explain, with equations, how ozone is formed in the stratosphere.

_____

_____

_____

_____

_____

_____

3 marks
Total 7 marks

Question 4

For the **unbalanced** equation:

$$H_2S(aq) + Cr_2O_7^{2-}(aq) + H^+(aq) \rightarrow Cr^{3+}(aq) + H_2O(l) + S(s)$$

answer the following questions.

a. Determine the oxidation number of the Cr atom in $Cr_2O_7^{2-}$

1 mark

b. Identify the species that has been oxidised in the reaction. Explain your answer.

2 marks

c. Write the oxidation half-equation (states not required).

1 mark

d. Write the reduction half-equation (states not required).

1 mark

e. Use your half-equations to write the balanced overall reaction (states not required).

1 mark
Total 6 marks

Question 5

A student takes 200 mL of 0.050 M H_2SO_4 (aq).

a. Determine the pH of the solution assuming complete ionisation.

2 marks

b. Calculate the number of mol of H^+ in the solution.

2 marks

c. The solution is then diluted to 1.0 litre by the addition of distilled water. Calculate the pH of the diluted solution.

1 mark

d. Calculate the volume of 0.10 M NaOH needed to neutralise the solution.

2 marks
Total 7 marks

Question 6

Three experiments were conducted to establish an electrochemical series for metallic elements X, Y and Z. 1.00 M solutions of XNO_3, $Y(NO_3)_3$, and $Z(NO_3)_2$, were placed in each of the three beakers. A strip of each metal was placed in the appropriate beaker to construct a half-cell. Half-cells were connected via an external circuit containing a voltmeter and an internal circuit (salt bridge). Three cells were constructed but the direction of electron flow was only recorded for cells 1 and 2 as shown in the Table below.

Cell 1	electron flow from Z to X
Cell 2	electron flow from Y to Z

a. For cell 1, neatly draw the **fully labelled** experimental setup including polarities, anode/cathode, and electron flow.

3 marks

b. Write ionic half equations for the reaction occurring at each electrode in **cell 1**.

i. Electrode Z

_____

ii. Electrode X

_____ 2 marks

c. Cell 3 involves X and Y. Which way will electrons flow in cell 3? _____

1 mark

d. List the symbols of the three metals in order of **increasing** reductant strength. _____ _____ _____ 1 mark

e. **i.** Give the formula of a salt that might have been used in the salt bridge. _____

1 mark

ii. Explain, **in specific detail,** the movement of cations and anions in the salt bridge

_____

_____

_____

_____

2 marks

Total 10 marks

Question 7

a. Aqueous silver ions, Ag^+ ions, form a precipitate with aqueous XO_4^{3-}. Write a balanced equation for the reaction, including state symbols.

2 marks

b. When 41.2 mL of a solution of 0.2040 M $Ag^+(aq)$ aqueous silver ions is added to a solution containing an excess of XO_4^{3-} ions, 1.172 g of the precipitate is formed.

i. Calculate the amount (in moles) of Ag^+ ions used in the reaction.

1 mark

ii. Calculate the amount (in moles) of the precipitate formed.

2 marks

iii. Calculate the molar mass of X. Show all working.

2 marks
Total 7 marks

Question 8

Understanding of acids and bases has changed since Arrhenius first developed his theory. Although an acid–base reaction is known as neutralisation, the resulting salt solution is not always neutral. For example, a solution of the salt sodium sulfate is neutral, but a solution of sodium ethanoate is basic.

a. Write a balanced equation to describe the formation of sodium sulfate from an acid–base reaction (states may be omitted).

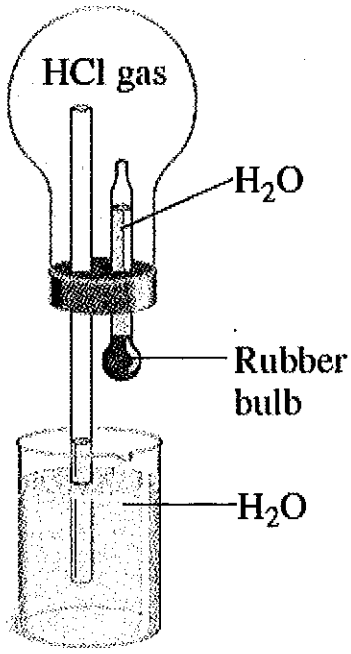
2 marks

b. Explain why a solution of sodium ethanoate, CH_3COONa, is basic, while a sodium sulfate solution of the same concentration has a pH of 7.0. Write an ionic equation(s) to describe any reactions (states may be omitted).

3 marks
Total 5 marks

Question 9

Consider the experimental apparatus shown below.



When a small amount of water is introduced into the round-bottomed flask by squeezing the bulb of the teat pipette, water is squirted upward out of the long glass tubing creating a fountain effect. Explain this observation.

3 marks

END OF EXAMINATION

SECTION A (1 mark for each correct response) **20 marks**

1.	D	2.	D	3.	C	4.	C	5.	C
6.	B	7.	B	8.	A	9.	B	10.	D
11.	A	12.	C	13.	A	14.	D	15.	D
16.	D	17.	C	18.	D	19.	D	20.	C

Comments on answers in Section A

Question 1
The substance with the least number of moles will have the least number of molecules. Given the mass of each is the same, the substance with the largest molar mass will result in the smallest number of mole. **Correct Answer: D**

Question 2
$n(NH_4)_2CO_3 = 0.50$; there are 3 ions per unit (cluster).
$n(ions) = 1.5$ mol ; $N(ions) = n \times N_A = 1.5 \times 6.0 \times 10^{23} = 9.0 \times 10^{23}$ **Correct answer: D**

Question 3
$c = n / V \rightarrow V = n / c$ $V = 0.100 / 0.125 = 0.800$ L = 800 mL **Correct answer: C**

Question 4
$d = m / V$ Neither m or V changes so the density does not change **Correct Answer: C**

Question 5
Gases will not behave ideally if the forces between molecules come into play. This happens when they are forced closer together or when they slow down. This happens under pressure and at low temperature. **Correct Answer: C**

Question 6
$n(CO_2) = m/M = 2.2 / 44 = 0.050$ mol.
$n(CO) = n(CO_2) = 0.050$; $m(CO) = n \times M = 0.050 \times 28 = 1.4$ g
m(flask) = 80.0 + 1.4 = 81.4 g **Correct answer: B**

Question 7
$n(SO_2) = n(O_2)$; N(molecules) must be the same. **Correct answer: B**

Question 8
The gas which occupies the biggest volume will be the one with the greatest number of mole. Need the one with the smallest molar mass, i.e. CH_4 **Correct answer: A**

Question 9
Use volume ratios as volume is directly proportional to the number of mole at constant temperature and pressure.
$V(SO_2)_{\text{reacting}} = 50$ mL ; $V(O_2)_{\text{reacting}} = 25$ mL
$V(SO_2)_{\text{reacting}} = V(SO_3)_{\text{produced}} = 50$ mL **Correct answer: B**

Question 10
Photosynthesis uses CO_2 **Correct answer: D**

Question 11
N_2 makes up approximately 79% of the atmosphere. **Correct answer: A**

Question 12
Both $(COOH)_2$ and H_2SO_4 are diprotic but H_2SO_4 but is a strong acid whereas $(COOH)_2$ is a weak acid. **Correct Answer: C**

Question 13
The conjugate base (NO_3^-) of a strong acid (HNO_3) would have the least tendency to accept protons. **Correct Answer: A**

Question 14
In answer B, it is only the HPO_4^{2-} ion which accepts protons. **Correct Answer: D**

Question 15
The substance must be a base to increase pH and fully dissociate /or ionise to give high electrical conductivity. Both NH_3 and NaOH are bases but NH_3 is a weak base only. **Correct Answer: D**

Question 16
For **X** at pH = 1, $[H^+] = 0.1$ M ; For **Y** at pH = 2, $[H^+] = 0.01$ M
$[H^+]$ in **X** is ten times that in **Y**. **Correct Answer: D**

Question 17
All carbonates decompose to give CO_2 **Correct Answer: C**

Question 18
The carbonated tap water would contain more ions because of the ionisation of H_2CO_3 formed from dissolved CO_2. **Correct Answer: D**

Question 19
From the Electrochemical Series, we need to consider the following redox pairs:
Fe^{3+}/ Fe^{2+}
Sn^{2+}/ Sn
Ni^{2+} / **Ni**
Fe^{2+}/ Fe
Zn^{2+}/ Zn

The oxidant must be higher in the series than the reductant to predict reaction. This is only true for the bolded pair. **Correct Answer: D**

Question 20
The reaction must involve both oxidation and reduction so A is not possible as the O atoms are not changing oxidation number. B makes no sense with H^+ and OH^- on opposite sides. D is not balanced. **Correct Answer: C**

SECTION B

Question 1 (6 marks)

a. $n(HCl) = m / M = 48.2 / 36.5 = 1.32$ mol **1 mark**

MnO_2 + 4HCl

n_i 0.320 1.32

n_r 0.320 1.28 (mol ratio 1:4) **1 mark**

HCl in excess by 0.04 mol **1 mark** $m(HCl) = n \times M = 0.04 \times 36.5 =$ 1.46 g **1 mark**

b. $n(Cl_2) / n(MnO_2) = 1:1$ **1 mark**; $n(Cl_2) = n \times M = 0.320 \times 71.0 = 22.7$ g **1 mark**

Question 2 (7 marks)

a. $PV = nRT$ therefore $P = nRT / V$

$n(CO_2) = m / M = 0.066 / 44.0 = 0.0015$ mol **1 mark**

$P = 0.0015 \times 8.31 \times 303 / 4.6$ **1 mark** for correct substitution $= 0.821$ kPa **1 mark**

b. $PV = nRT$ therefore $n = PV/ RT$

$P(O_3) = 1.0 \times 10^{-3} \times 101.3 = 0.101$ kPa **1 mark** for pressure conversion from atm to kPa

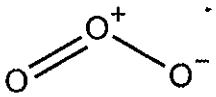
$n(O_3) = 0.101 \times 1.0 / 8.31 \times 250$ **1 mark** for correct substitution

$= 4.86 \times 10^{-5}$ mol **1 mark**

$N(O_3)_{molecules} = 4.86 \times 10^{-5} \times 6.02 \times 10^{23} = 2.93 \times 10^{19}$ **1 mark**

Question 3 (7 marks)

a. O=O **1 mark**



1 mark

b. Any two of the following **(1 mark each)**

- ozone has an odour, oxygen gas is odourless
- ozone can cause respiratory problems, oxygen does not
- ozone is a pale blue gas, oxygen is colourless
- ozone is a sanitiser, oxygen is not
- ozone can destroy organic materials, oxygen does not

c. oxygen molecules can be broken down into oxygen radicals by particular wavelengths of UV light **1 mark**

$O_2(g) \rightarrow 2\,O^{\bullet}$ **1 mark**

The radicals then react with oxygen molecules to produce ozone.

$O_2(g) + O^{\bullet} \rightarrow O_3(g)$ **1 mark**

Question 4 (6 marks)

a. $2\,Cr + 7(-2) = -2$ therefore $2Cr = 12+$ and each $Cr = +6$ **1 mark**

b. The S atoms have increased from an oxidation number of -2 to 0. **1 mark**

An increase in oxidation number is oxidation. H_2S has been oxidised. **1 mark**

c. $H_2S \rightarrow S + 2H^+ + 2e^-$ **1 mark**

d. $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$ **1 mark**

e. $3H_2S + Cr_2O_7^{2-} + 8H^+ \rightarrow 2Cr^{3+} + 7H_2O + 3S$ **1 mark**

Question 5 (7 marks)

a. $[H_2SO_4] = 0.050$ M but two H^+ ions are produced when each acid molecule ionises. Therefore $[H^+] = 0.10$ M **1 mark**; $pH = -\log_{10}[H^+] = 1.0$ **1 mark**

b. $n(H_2SO_4) = c \times V = 0.050 \times 0.200 = 0.01$ mol **1 mark**

$n(H^+) = 2 \times n(H_2SO_4) = 2 \times 0.01 = 0.02$ mol **1 mark**

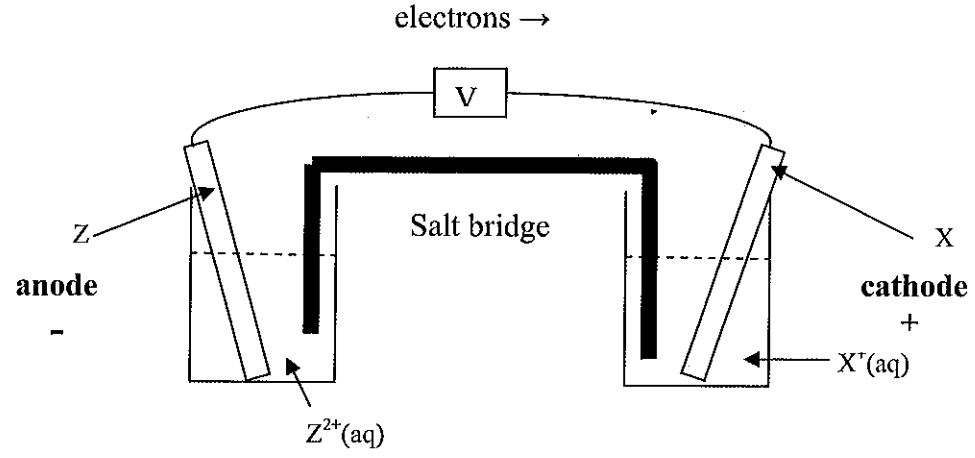
c. $[H^+] = n / V = 0.020 / 1.0 = 0.020$ M $pH = -\log_{10}[H^+] = 1.70$ **1 mark**

d. $n(NaOH) = n(OH^-) = n(H^+) = 0.020$ mol **1 mark**

$v(NaOH) = n / C = 0.020 / 0.10 = 0.20$ L $= 200$ mL **1 mark**

Question 6 (10 marks)

a.



- Z as the negative electrode **1 mark**
- Z as the anode **1 mark**
- Generally correct diagram **1 mark**

b **i.** $Z(s) \rightarrow Z^{2+}(aq) + 2e^-$ **1 mark**
ii. $X^+(aq) + e^- \rightarrow X(s)$ **1 mark**

c. From the data, the order of half-cells can be deduced as follows:
X^+/X
Z^{2+}/Z
Y^{3+}/Y
Electrons flow from the lowest placed half-cell i.e. from Y to X **1 mark**

d. Increasing reducing strength is X, Z, Y **1 mark**

e. **i.** An example would be KNO_3 **1 mark**
ii. The NO_3^- anions from the salt bridge move towards the anode half-cell to balance the production of Z^{2+} **1 mark.** The K^+ cations move towards the cathode half-cell to balance the removal of X^+ ions. **1 mark**

(If a student argues that the anions flow to the anode half-cell and cations flow to the cathode, half-cell award 1 mark only.)

Question 7 (7 marks)

a. $3Ag^+(aq) + XO_4^{3-}(aq) \rightarrow Ag_3XO_4(s)$ Correct balance **1 mark**; Correct states **1 mark**

b. **i.** $n(Ag^+) = c \times V = 0.2040 \times 41.2 \times 10^{-3} = 8.40 \times 10^{-3}$ mol **1 mark**
ii. $n(Ag_3XO_4) / n(Ag^+) = 1/3$ **1 mark**
$n(Ag_3XO_4) = 8.40 \times 10^{-3} / 3 = 2.80 \times 10^{-3}$ mol **1 mark**
iii. $m(Ag_3XO_4) / M(Ag_3XO_4) = 2.80 \times 10^{-3}$
$M(Ag_3XO_4) = 1.172 / (2.80 \times 10^{-3}) = 418.6$ **1 mark**
$3 \times 107.9 + X + 4 \times 16.0 = 418.6 \rightarrow X = 30.9$ **1 mark**
(If a student 'guesses' that X is phosphorus (31.0) but shows no working, no marks awarded.)

Question 8 (5 marks)

a. $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$
Correct formulae **1 mark**; Correct balance **1 mark**

b. The ethanoate ion, CH_3COO^- ion has an appreciable reaction with water to produce OH^- ions. **1 mark**

$CH_3COO^-(aq) + H_2O(l) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$ **1 mark**

whereas the sulfate ion has negligible reaction with water. **1 mark**

Question 9 (3 marks)

The polar molecules of HCl are very soluble in water. **1 mark**
This greatly reduces the gas pressure in the flask. **1 mark**
The surrounding air pressure outside the flask pushes the water up the tube to create the fountain. **1 mark**

END OF SUGGESTED SOLUTIONS