This section contains 20 multiple choice questions.
For each question choose the response that is correct or that best answers the question.
Indicate your answer **on the answer sheet provided**.
Choose only **one** answer for each question.
A correct answer scores 1, an incorrect answer scores 0. Marks will **not** be deducted for incorrect answers.No marks
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 0.5 mol of sodium carbonate, Na_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 0.200 mol of ethanoic acid, CH_3COOH, has a concentration of 0.250 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

The majority of nitrogen found in the biosphere is present as

A. N_2

B. NO_3^-

C. NH_3

D. NO_2

Question 6

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

A. NO_3^-

B. NH_3

C. SO_3^{2-}

D. CO_3^{2-}

Question 7

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 8

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 9

Which of the following is a weak, diprotic acid?

A.   HCOOH

B. H_2SO_4

C. $(COOH)_2$

D. C_2H_2

Question 10

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 the same amount in moles of 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 11

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

$$2SO_2(g) + O_2 \rightarrow 2SO_3(g)$$
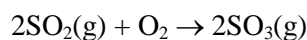
The maximum volume of sulphur trioxide, in litres, that can be prepared from 60 L of SO_2 and 60 L of O_2, **if all gases are measured at the same temperature and pressure and assuming the reaction goes to completion**, is

A.   30

B.   60

C.   90

D.   120

Question 12

A Brønsted-Lowry acid is defined as

A.   an electron donor

B.   an electron acceptor

C.   a proton donor

D.   a proton acceptor

Question 13

The pH of a solution of 0.1 M K_2HPO_4 (aq) was found to be 9.3. The best explanation of this is

A.   The K^+ ions form KOH in solution.

B. K_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 14

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. NH_3

D.   NaOH

Question 15

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

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

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

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

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

Question 16

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

Question 17

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 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

An experiment was conducted to determine the reactivity series for metals P, Q, R and S by examining any reactions which occur between the metals and solutions of the metal ions. Some of the results of the experiment were:

- Metal P reacts with metal ion S^{2+} but not with metal ion Q^{2+}
- Metal Q reacts with metal ion S^{2+} but not with metal ion R^{2+}

Question 19

Which of the following identifies the decreasing reactivity of these metals, starting with the most reactive metal?

A.   Q, P, R, S

B.   R, Q, P, S

C.   S, Q, P, R

D.   Q, R, S, P

⇌Question 20

A galvanic cell is constructed using P^{2+}/P and R^{2+}/R half-cells.

Which of the following shows the expected reaction at the anode of this galvanic cell?

A. $R(s) \rightleftharpoons R^{2+}(aq) + 2e^-$

B. $P(s) \rightleftharpoons P^{2+}(aq) + 2e^-$

C. $R^{2+}(aq) + 2e^- \rightleftharpoons R(s)$

D. $P^{2+}(aq) + 2e^- \rightleftharpoons P(s)$

SECTION B: SHORT-ANSWER QUESTIONS (64 marks, 65 minutes)

This section contains 8 short-answer questions. 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 to 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

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 an aqueous solution of 0.2040 M Ag^+ 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.

_____

_____

_____

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

_____

_____

_____

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

_____

_____

_____

1 + 2 + 2 = 5 marks

Total 7 marks

Question 2

A neutralisation reaction between barium hydroxide and sulphuric acid was performed.

a. Write a balanced chemical equation for the reaction between the barium hydroxide and sulphuric acid solutions.

_____

2 marks

b. Calculate the mass of barium hydroxide powder needed to make 100.0 mL of 0.050 M solution.

_____

_____

_____

_____

2 marks

c. Explain why barium hydroxide conducts electricity when dissolved in water.

_____

_____

_____

1 mark

d. If 5.5 mL of a sulphuric acid solution was required to exactly neutralise a 20.0 mL aliquot of barium hydroxide, calculate the molarity of the sulphuric acid used in this experiment.

_____

_____

_____

_____

_____

3 marks

e. State which pieces of laboratory equipment would be used to dispense the required volumes of barium hydroxide and sulphuric acid solutions.

_____

_____

2 marks

Total 10 marks

Question 3

Ammonia gas has a high solubility in water of 75.1 L in 100 mL of water at 20 °C.

a. With the aid of a balanced chemical equation, explain why water containing dissolved ammonia would appear pink in the presence of phenolphthalein.

_____

_____

_____

_____

2 marks

b. Using a labelled diagram, including the structural formulas of ammonia and water molecules, explain how ammonia dissolves in water.

_____

_____

_____

3 marks

c. The solubilities, in water, of two other gases are shown in the table below.

Gas	Solubility of gas (mL per 100 mL of water)		
	0 °C	**20 °C**	**40 °C**
oxygen	4.8	3.3	2.5
sulfur dioxide	7980	4250	2170

i. Describe an environmental problem caused by the high solubility of sulphur dioxide in water.

_____

_____

_____

_____

ii. Some industries produce heated waste water. With reference to the information in the table of gas solubilities, explain the environmental problem caused by returning this heated water to natural waterways.

_____

_____

_____

_____

2 + 2 marks

Total 9 marks

Question 4

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

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 5

For the **unbalanced** equation:

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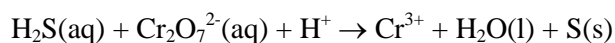
answer the following questions.

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).
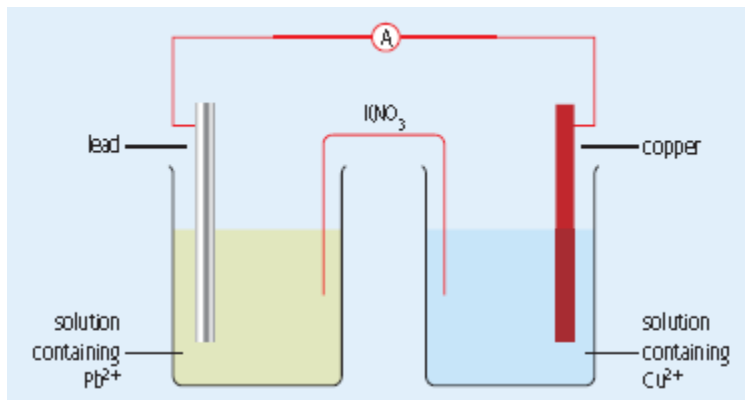
_____

1 mark

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

_____

1 mark

Total 6 marks

Question 6

A galvanic cell was made from copper and lead, as shown below.

a. Identify the reductant and oxidant that are reacting in this cell and write balanced half equations for their

    reactions.

    _____

    _____

    _____

    _____

    _____

                                                                                    4 marks

b. Write the balanced overall ionic equation for the cell reaction.

    _____

                                                                                    1 mark

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

    _____

    _____

    _____

                                                                                    2 marks

d. Explain why the salt used is KNO_3 and not K_2SO_4

    _____

    _____

                                                                                    1 mark

e. Which electrode would be the cathode?

    _____

                                                                                    1 mark

                                                                              Total 9 marks

Question 7

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

_____

_____

_____

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_____

_____

_____

_____

_____

_____

4 marks

Total 7 marks

Question 8

Nitrogen gas composes 78% of air at sea level. Nitrogen is used by all living organisms and is an important raw material in the industrial production of chemicals.

a.   Nitrogen gas must be 'fixed' before it can be used by living things.

    i.   Explain the meaning of 'fixed' in this context.

_____

_____

_____

    ii.   Give an example of nitrogen being 'fixed' in a natural, non-biological process.

_____

_____

_____

<div align="right">1+ 1 = 2 marks</div>

b.   An important industrial use of nitrogen is the manufacture of nitric acid (HNO_3). Initially, nitrogen and hydrogen gases are reacted to form ammonia gas which is then oxidised to produce the acid in a series of steps.

    i.   In ammonia production, air is used as the source of nitrogen gas in the reaction vessel rather than pure nitrogen gas. Suggest a reason for this.

_____

_____

_____

    ii.   The final concentration of nitric acid from the process is 68 % (m/v). Calculate the pH of the acid at this concentration.

_____

_____

_____

_____

_____

_____

<div align="right">1 + 3 = 4 marks</div>

c. The principles of green chemistry are used extensively in the modern manufacture of nitric acid.

    i. One of these principles is to maximise atom economy. Calculate the percentage atom economy for the modern method which uses the chemical reaction shown below.

$$NH_3(g) + 2O_2(g) \rightarrow HNO_3(aq) + H_2O(l)$$
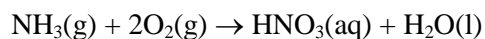
    ii. This simplified diagram shows the important steps in the modern manufacture of nitric acid.
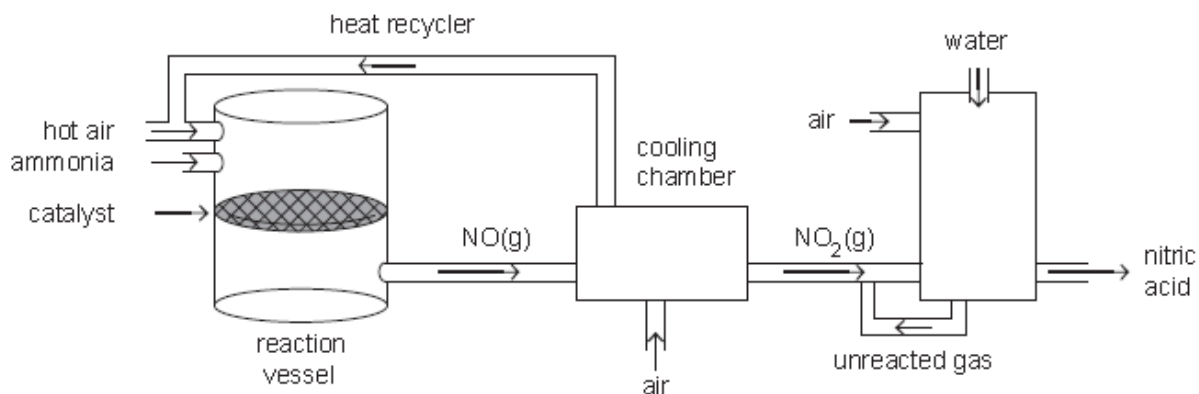
    Identify **two** applications of green chemistry used in the manufacturing process shown in the diagram.

$2 + 2 = 4$ marks

Total $= 10$ marks

END OF QUESTION AND ANSWER BOOKLET