Oxford Cambridge and RSA

Thursday 12 January 2023 – Morning

Level 3 Cambridge Technical in Applied Science

05847/05848/05849/05874/05879 Unit 2: Laboratory techniques

Time allowed: 2 hours
C341/2301

You must have:
- the Data Sheet
- a ruler (cm/mm)

You can use:
- a scientific or graphical calculator
- an HB pencil

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number						Candidate number				

First name(s) ______________________

Last name ______________________

Date of birth	D	D	M	M	Y	Y	Y	Y

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.

INFORMATION
- The total mark for this paper is **90**.
- The marks for each question are shown in brackets **[ ]**.
- The Periodic Table is on the back page.
- This document has **28** pages.

ADVICE
- Read each question carefully before you start your answer.

Answer **all** the questions.

1 Anika is leading a team of scientists in Ghana working for the World Health Organization (WHO).

She is studying sickle cell disease, a life-threatening inherited blood disorder.

Anika gives her team the following information:

- People with sickle cell disease inherit two copies of the sickle cell gene, one from each of their parents.
- Some people are carriers for this disease.
- Carriers do not have full symptoms of sickle cell disease and they have the advantage of being resistant to malaria (a serious disease that is transmitted via mosquito bites).
- Ghana is an African country with a population of 28 million people, and malaria is always present in the population.

Anika wants to know what proportion of the **entire population of Ghana** are sickle cell carriers. She and her team do this by genetically testing a sample of the population.

Anika chooses to sample a village in Ghana. The total population of the village is 250. There are 105 men, 95 women and the remaining 50 are children.

(a) Anika's first plan is to test everyone in the village.

(i) Circle the kind of sample that this represents.

biased **random** **representative** **whole**

[1]

(ii) Put a tick (✓) in **one** box that **best** explains why it is this kind of sample.

All the people in the village would be in the sample ☐

Over 100 people would be in the sample ☐

There are more men than women in the village ☐

There would be a range of men, women and children in the sample ☐

[1]

(b) Anika's team of scientists do not have enough time or resources to sample everyone in the village.

Instead, they put numbered tickets into a container, each person in the village takes a ticket and only those with an even-numbered ticket are tested.

(i) Circle the **two** kinds of sample that this represents.

biased **random** **representative** **whole**

[1]

(ii) Put a tick (✓) in the **two** boxes that **best** explain your answer.

Anika did not choose the selection herself	☐
Half of the people in the village would be in the sample	☐
Over 100 people would be in the sample	☐
There would be a range of men, women and children in the sample	☐

[1]

(c) A member of her team thinks that more people should be tested.

State how this would affect the reliability of the results.

.... **[1]**

(d) Two methods can be used to obtain DNA samples, either a cheek swab or a blood test.

Fig. 1.1 shows a cheek swab being taken.

Fig. 1.2 shows a hypodermic syringe being used to take a blood sample.

Fig. 1.1

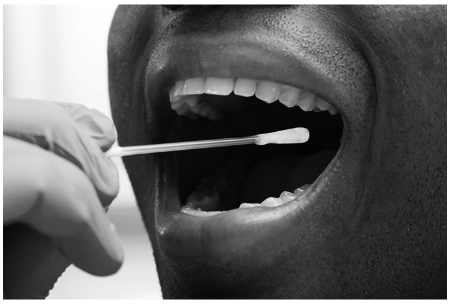
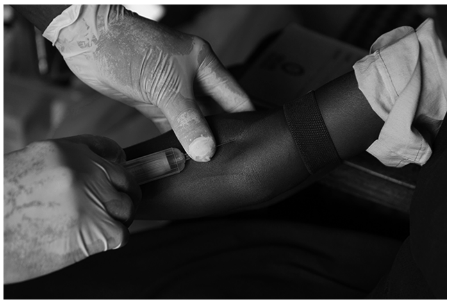


Fig. 1.2



After carrying out a risk assessment for the two methods, Anika chooses the cheek swab method.

(i) Use the information shown in **Fig. 1.1** and **Fig. 1.2** to describe **one** health and safety reason why Anika chooses the cheek swab method.

.... **[1]**

(ii) Suggest **one** further reason, other than health and safety, why Anika chooses the cheek swab method.

.... **[1]**

(iii) Describe **one** hazard that the scientists in Anika's team may encounter as they take cheek swab samples from the patients.

....

.... **[1]**

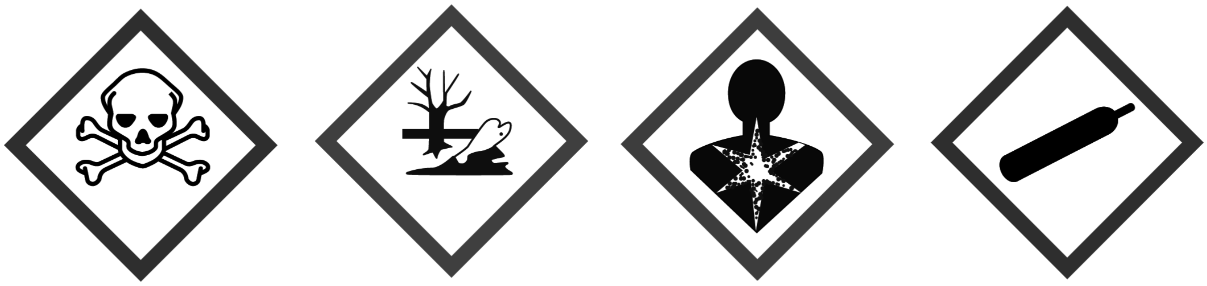
(iv) Suggest **one** hazard that **all** members of Anika's team may encounter in Ghana, even those not taking samples from the patients.

.... **[1]**

(e) Anika's team takes the waste sample materials to a nearby university laboratory for disposal.

(i) The waste must be labelled with a hazard warning symbol.

Put a tick (✓) under the correct hazard warning symbol.



....

[1]

(ii) Complete the sentences about disposal of the waste sample materials using words from this list.

The words may be used once, more than once or not at all.

audio	**autoclaving**	**burying**	**freezing**	**patient**
serial number	**video**	**waste operator**	**written**	

1 The used cheek swabs should be disposed of by ....

2 .... records of the type and quantity of waste must be kept. These records should also include the date and time that the waste was processed and the name of the ....

[2]

(f) Anika's team tested 125 people in the village. They found that 22 of the people tested were sickle cell disease carriers.

(i) Estimate the percentage of people in the village who are carriers.

% of people who are carriers = ... % **[1]**

(ii) Suggest why this percentage might not be a very accurate estimate of the percentage of people in the whole of Ghana who are sickle cell disease carriers.

.... **[1]**

2 Amit is learning about the molecular biology techniques of PCR and gel electrophoresis.

(a) Draw a line to link the name of each technique to its function.

Technique	**Function**
PCR	To amplify specific sequences of nucleic acid
Gel electrophoresis	To purify sequences of nucleic acid
	To extract nucleic acid from cells
	To separate nucleic acid according to size

[2]

(b) A PCR mixture requires a number of essential components.

Complete the sentences about the PCR components using words from this list.

The words may be used once, more than once or not at all.

amino acids **amylase** **glucose** **nucleotides**

polymerase **primers** **sucrase**

The enzyme that synthesises DNA strands in PCR is called ....

The monomers used in DNA synthesis are ....

[2]

(c) PCR requires three steps repeated many times.

Draw a line to link the name of each step to its correct description.

Step	**Description**
Denaturation	Primers bind to specific complementary sequence
Annealing	Double stranded DNA separated into single strands
Elongation	Nucleotide monomers assembled into a DNA strand

[2]

(d) The number of DNA copies obtained from one gene via PCR can be calculated using the equation:

Number of copies = 2^n where n is the number of PCR cycles

Calculate how many copies can be produced from 30 cycles of PCR.

Give your answer to **one** significant figure.

.... **[1]**

(e) Explain why heat-stable enzymes are used in PCR.

....

....

.... **[2]**

(f) The DNA fragments obtained from PCR are separated by gel electrophoresis.

(i) Draw **one** line to link the charge of the DNA fragments to the correct electrode they migrate towards.

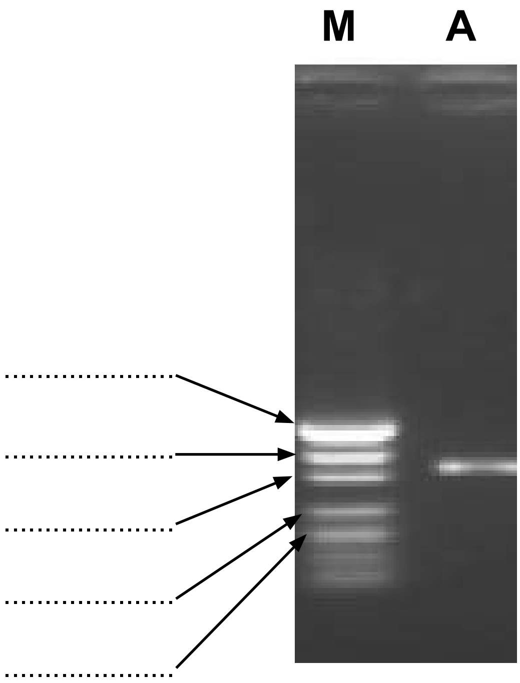
Charge	**Electrode**
Positive	Anode
Neutral	Cathode
Negative	Dynode
Dipole	Cestode

[1]

(ii) Gel electrophoresis of a PCR reaction is shown below.

The size markers are in lane **M**.

The PCR fragment is in lane **A**.



The size markers are:

110bp **404bp** **331bp** **242bp** **489bp**

Label the markers with the correct sizes in the spaces to the left of the figure.
[1]

(iii) Use the size markers in lane **M** to estimate the size of the PCR fragment in lane **A**.

.... bp **[1]**

(g) Suggest why shorter DNA fragments move faster through the agarose gel during electrophoresis.

.... **[1]**

3 **(a)** Sara is a student learning about acid–base titrations.

The pieces of laboratory glassware that she could use are listed in **Fig. 3.1**.

Fig. 3.1

- 50 cm^3 burette
- 100 cm^3, 250 cm^3 and 1 dm^3 beakers
- 10.0 cm^3 and 25.0 cm^3 one-mark pipettes
- 10 cm^3 and 25 cm^3 measuring cylinders
- 100.0 cm^3, 250.0 cm^3 and 1.0 dm^3 volumetric flasks
- 250 cm^3 conical flask.

She has been asked to carry out a titration to determine the concentration of a solution of ammonia, $NH_3(aq)$. She decides to titrate a known volume of the ammonia solution against a standard solution of 0.100 mol dm^{-3} hydrochloric acid.

(i) Sara is provided with 10.0 mol dm^{-3} hydrochloric acid.

Describe how she would use this solution to prepare 1 dm^3 of 0.100 mol dm^{-3} hydrochloric acid.

In your answer you should name the two pieces of glassware from **Fig. 3.1** that she would need.

....

....

....

....

....

.... **[3]**

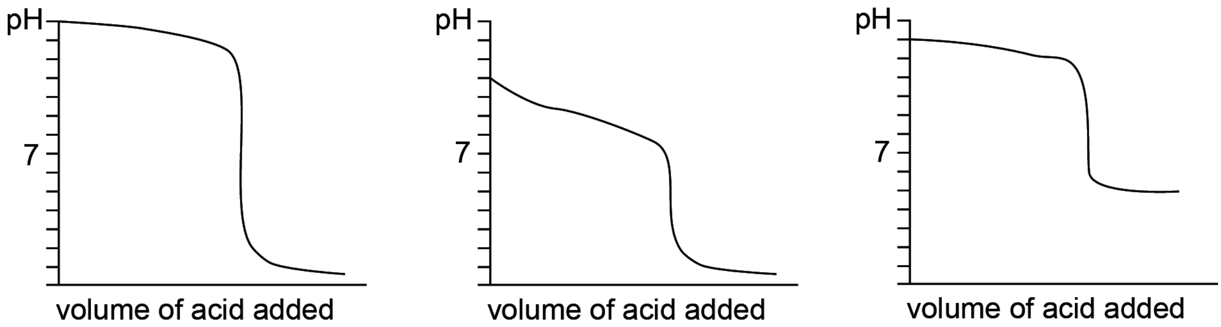
(ii) Ammonia solution is a weak base and hydrochloric acid is a strong acid.

Three sketches, **A**, **B** and **C** of acid–base titration curves are shown below.

Which curve **A, B** or **C** applies to the titration of ammonia with hydrochloric acid?

Circle the correct letter.

A **B** **C**



[1]

(iii) Sara must choose the correct indicator for the titration between ammonia and hydrochloric acid.

The pH range of some common indicators are shown in the table.

Indicator	**pH range**
Methyl Orange	3.2 - 4.4
Litmus	5.0 - 8.0
Bromothymol Blue	6.0 - 7.6
Phenolphthalein	8.2 - 10.0

Use your answer to **(a)(ii)** and the table to determine which indicator Sara should use.

Explain your answer.

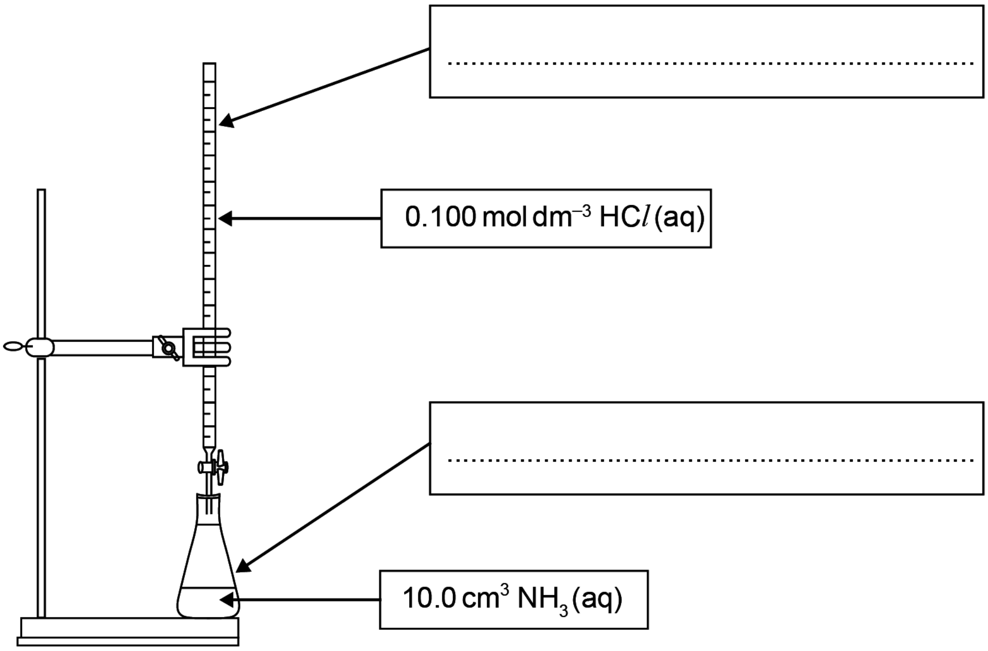
- Choice of indicator ....
- Explanation ....

....

[2]

(iv) Sara sets up the apparatus to carry out a titration, as shown in **Fig. 3.2**.

Fig. 3.2



Use **Fig. 3.1** to select the two pieces of glassware shown in **Fig. 3.2**.

Write the name of each piece of glassware in the two boxes in **Fig. 3.2**.

[1]

(v) Use the data below to calculate the concentration, in mol dm^{-3}, of the ammonia solution.

- Volume of ammonia solution = 10.0 cm^3
- Volume of 0.100 mol dm^{-3} HCl used in the titration = 16.1 cm^3
- 1 mole of ammonia reacts with one mole HCl

Concentration of ammonia solution = ... mol dm^{-3} **[3]**

(b) Zac is a technician working in a pharmacology laboratory.

- A common drug for the treatment of malaria is *mefloquine*. *Mefloquine* is a weak base and is given to the patient as a tablet.
- One of Zac's tasks is to determine the mass of *mefloquine* in one tablet.
- Zac dissolves one tablet of *mefloquine* in water and makes up the solution to 100.0 cm^3.
- He uses an autotitrator to determine the concentration of *mefloquine* in the solution by titrating 5.0 cm^3 portions of the solution against 0.01 $mol\,dm^{-3}$ $HCl(aq)$.

(i) State why it is not necessary to use an indicator when using an autotitrator.

.... **[1]**

(ii) Autotitrators have advantages and disadvantages in comparison to manual titrations.

Put a tick (✓) in the box(es) next to **all** the advantages of using an autotitrator.

It is not necessary to make up accurate standard solutions	☐
Less titrant is used	☐
Results can be exported electronically to another device	☐
Smaller sample is required	☐
The equipment is cheaper	☐
The results are more accurate	☐

[3]

(iii) Zac uses his titration results to calculate that the concentration of the *mefloquine* solution was 0.0066 $mol\,dm^{-3}$. The molar mass of *mefloquine* is 378 $g\,mol^{-1}$.

Calculate the mass in mg, of *mefloquine* in one tablet.

Give your answer to **3** significant figures.

Mass of *mefloquine* in one tablet .... mg **[3]**

4 **(a)** AIDS is caused by the Human Immunodeficiency Virus (HIV).

Layla is a researcher investigating HIV.

She is using microscopy to identify the features of HIV particles and cells infected with HIV.

Fig. 4.1 shows an electron micrograph of an HIV particle.

Fig. 4.2 is a light micrograph of cells, some of which are infected with HIV.

Fig. 4.1

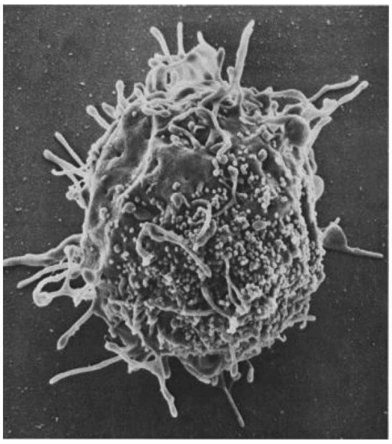
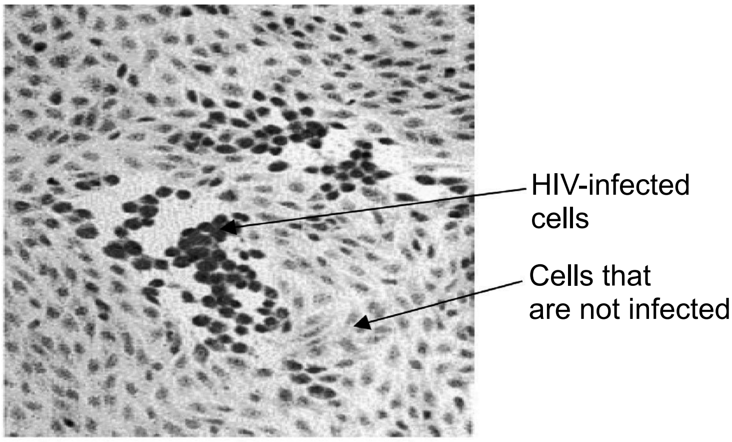


Fig. 4.2



(i) Measure the diameter of the HIV particle shown in **Fig. 4.1**.

Measurement = ... units .... **[2]**

(ii) The magnification of the electron microscope used to obtain the image in **Fig. 4.1** is ×300,000.

Use your answer to **(a)(i)**, to calculate the actual diameter of the HIV particle in mm.

Actual diameter of HIV particle = ... mm **[1]**

(iii) Draw a scale bar on **Fig. 4.1** that represents 100 nm.

[1]

(iv) Describe **one** feature of an HIV particle that can be seen in **Fig. 4.1**.

.... **[1]**

(v) Which organelle appears to be more dense in the HIV-infected cells in **Fig. 4.2**?

.... **[1]**

(vi) Describe **and** explain **one** advantage of light microscopy in comparison to electron microscopy.

....

....

.... **[2]**

(vii) Explain why individual HIV particles cannot be seen using a light microscope.

....

....

.... **[2]**

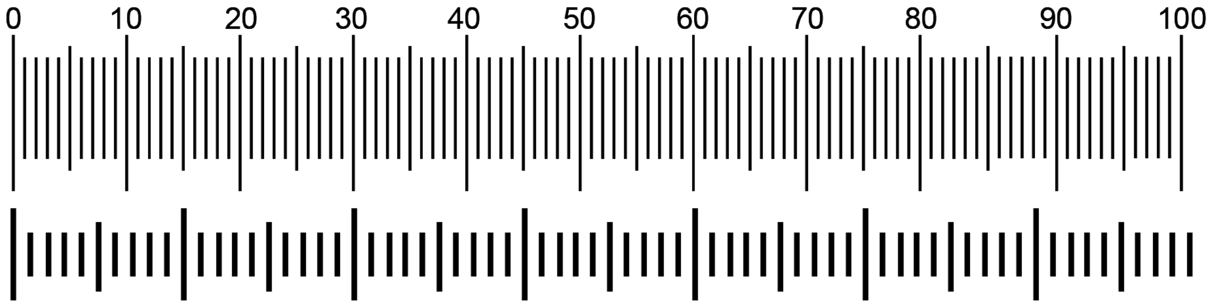
(b) Tom is also a researcher using microscopes.

He is measuring the size of animal cells using a light microscope fitted with an eyepiece graticule.

The figure below shows an eyepiece graticule alongside a stage micrometer. They are seen when using a light microscope.

The smallest graduations on the stage micrometer are 10 μm.

Eyepiece graticule



Stage micrometer

(i) Draw a double-headed arrow on the stage micrometer scale to represent 0.5 mm.

[1]

(ii) Select **two** suitable lines on the stage micrometer scale that would be useful for calibrating the eyepiece graticule.

Label the lines as **X1** and **X2**.

[1]

(iii) Calculate the actual length, in μm, that **one** graduation on the eyepiece graticule represents.

Actual length = ... μm **[2]**

(iv) Tom then measures the cells using the light microscope set at a different magnification.

State what Tom should do before he takes his measurements.

.... **[1]**

(v) To set the light microscope at a different magnification, Tom changes the objective lens from 40× to 100× but keeps the eyepiece lens and graticule the same.

Circle the correct word(s) to complete the sentences.

- The size of the scale on the eyepiece graticule appears:

  smaller **the same** **bigger**

- The size of the cells appears:

  smaller **the same** **bigger**

- Each graduation on the eyepiece graticule now represents:

  a shorter length **the same length** **a greater length**

[3]

Turn over for the next question

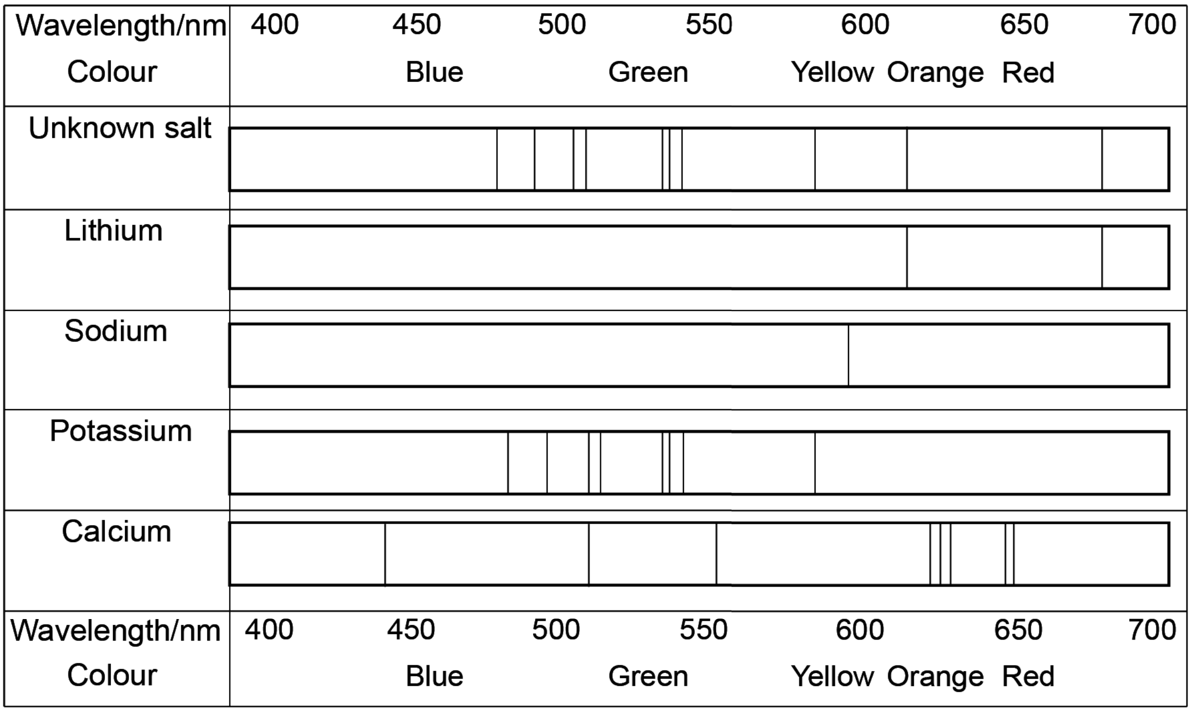
5 Ali is learning about Atomic Emission Spectroscopy (AES) and ion chromatography.

(a) Ali uses Atomic Emission Spectroscopy (AES) to identify the cations present in a sample of an unknown salt.

He compares the spectrum of the unknown salt with spectra of known cations.

His results are shown in **Fig. 5.1**. The position of each line indicates the observed colour.

Fig. 5.1



Describe the key principles of AES and use the information in **Fig. 5.1** to identify the cations in the unknown salt.

Explain with reference to the spectra how you reached your conclusion.

....

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....

.... **[6]**

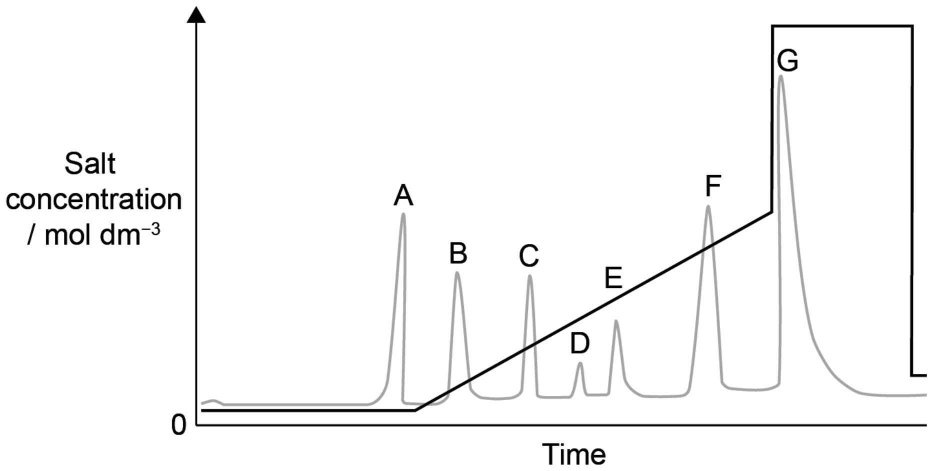
(b) Ali uses ion chromatography to separate proteins in a sample of brain tissue.

He follows the steps listed below:

- The sample is loaded onto an ion exchange column at a particular pH.
- The different proteins in the sample bind to the ion exchange resin, some binding more easily than others.
- Impurities are removed by washing the column with a very low concentration of salt solution before the salt gradient is applied.
- By gradually increasing the salt solution concentration, the different proteins are eluted (washed out) from the column at different times.
- A UV detector is used to detect each protein as it leaves the column.

Having completed the steps, Ali obtains the chromatogram shown below.

The grey line indicates the substances (**A** to **G**) eluted from the column, and the black line indicates the salt concentration.



(i) Complete the following sentences using words from the list to explain how this type of ion chromatography separates proteins.

charged	**high**	**impurities**	**low**
neutral	**salts**	**strongest**	**weakest**

- .... proteins will bind to the oppositely charged groups in the resin.
- A salt gradient is used to elute the different proteins. At .... salt concentrations, proteins having few charged groups are eluted and at .... salt concentrations, proteins with several charged groups are eluted.

[3]

(ii) State the letter of the protein that binds to the column the strongest.

.... **[1]**

(iii) State the letter of the protein which is the least abundant in the sample.

.... **[1]**

(iv) State the letter which indicates the impurities present in the sample.

.... **[1]**

(v) Explain why a UV detector can be used to detect the proteins as they emerge from the column.

.... **[1]**

(vi) Give **two** uses of ion exchange chromatography other than separating and purifying proteins.

....

....

.... **[2]**

6 **(a)** Kareem is a student learning how to culture bacteria in a laboratory.

He finds out that some bacteria are parasitic and must be cultured in a medium containing living animal cells.

It is important that Kareem uses aseptic technique to establish and maintain his cultures. To do this he learns how to sterilise equipment and materials correctly.

(i) Draw lines to link each equipment or material to be sterilised to the correct method of sterilisation.

Equipment or material to be sterilised	**Method of sterilisation**
Hard surfaces inside the work area	Filtering through a sterile membrane filter
Glassware	Autoclaving
Protein growth factors to add to the animal cell culture medium	Refrigeration
	Wiping with bactericidal solution

[3]

(ii) Kareem works at a controlled air flow cabinet.

Suggest **two** reasons for doing this.

1 ....

2 .... **[2]**

(iii) Kareem wears disposable gloves when working at the controlled air flow cabinet.

Suggest the likely impact of this on his bacterial cultures.

....

.... **[1]**

(iv) Give **two** other examples of laboratory work, not including the culture of microorganisms, that require aseptic technique.

1 ....

2 .... **[2]**

(b) Alex is also learning about aseptic technique in microbiology at college.

She is streaking bacteria onto an agar plate from a stock culture grown on an agar slope.

(i) Tick (✓) **one** box that shows why Alex first heats an inoculating loop in a flame until it glows red.

To avoid killing the inoculum ☐

To check for contamination ☐

To obtain clones of bacteria ☐

To prevent aerosols containing bacteria ☐

To sterilise the inoculating loop ☐

To test for lithium ions ☐

[1]

(ii) Tick (✓) **two** boxes that show why Alex allows the inoculating loop to cool down before dipping it into the stock culture of bacteria on an agar slope.

To avoid killing the inoculum ☐

To check for contamination ☐

To obtain clones of bacteria ☐

To prevent aerosols containing bacteria ☐

To sterilise the inoculating loop ☐

To test for lithium ions ☐

[2]

(c) The streaked plate is cultured in an incubator at 30 °C for 24 hours.

The plate is shown below.

A cluster of individual colonies have grown on the streaked plate.

Suggest **two** ways in which the individual colonies have grown on the plate.

1 ....

....

2 ....

....

[2]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined pages. The question numbers must be clearly shown in the margins – for example, 2(b) or 3(a)(i).

The Periodic Table of the Elements

Key
atomic number
Symbol
name
relative atomic mass

1 (1)	2 (2)	3	4	5	6	7	8	9	10	11	12	13 (3)	14 (4)	15 (5)	16 (6)	17 (7)	18 (0)
1 **H** hydrogen 1.0																	2 **He** helium 4.0
3 **Li** lithium 6.9	4 **Be** beryllium 9.0											5 **B** boron 10.8	6 **C** carbon 12.0	7 **N** nitrogen 14.0	8 **O** oxygen 16.0	9 **F** fluorine 19.0	10 **Ne** neon 20.2
11 **Na** sodium 23.0	12 **Mg** magnesium 24.3											13 **Al** aluminium 27.0	14 **Si** silicon 28.1	15 **P** phosphorus 31.0	16 **S** sulfur 32.1	17 **Cl** chlorine 35.5	18 **Ar** argon 39.9
19 **K** potassium 39.1	20 **Ca** calcium 40.1	21 **Sc** scandium 45.0	22 **Ti** titanium 47.9	23 **V** vanadium 50.9	24 **Cr** chromium 52.0	25 **Mn** manganese 54.9	26 **Fe** iron 55.8	27 **Co** cobalt 58.9	28 **Ni** nickel 58.7	29 **Cu** copper 63.5	30 **Zn** zinc 65.4	31 **Ga** gallium 69.7	32 **Ge** germanium 72.6	33 **As** arsenic 74.9	34 **Se** selenium 79.0	35 **Br** bromine 79.9	36 **Kr** krypton 83.8
37 **Rb** rubidium 85.5	38 **Sr** strontium 87.6	39 **Y** yttrium 88.9	40 **Zr** zirconium 91.2	41 **Nb** niobium 92.9	42 **Mo** molybdenum 95.9	43 **Tc** technetium	44 **Ru** ruthenium 101.1	45 **Rh** rhodium 102.9	46 **Pd** palladium 106.4	47 **Ag** silver 107.9	48 **Cd** cadmium 112.4	49 **In** indium 114.8	50 **Sn** tin 118.7	51 **Sb** antimony 121.8	52 **Te** tellurium 127.6	53 **I** iodine 126.9	54 **Xe** xenon 131.3
55 **Cs** caesium 132.9	56 **Ba** barium 137.3	57–71 lanthanoids	72 **Hf** hafnium 178.5	73 **Ta** tantalum 180.9	74 **W** tungsten 183.8	75 **Re** rhenium 186.2	76 **Os** osmium 190.2	77 **Ir** iridium 192.2	78 **Pt** platinum 195.1	79 **Au** gold 197.0	80 **Hg** mercury 200.6	81 **Tl** thallium 204.4	82 **Pb** lead 207.2	83 **Bi** bismuth 209.0	84 **Po** polonium	85 **At** astatine	86 **Rn** radon
87 **Fr** francium	88 **Ra** radium	89–103 actinoids	104 **Rf** rutherfordium	105 **Db** dubnium	106 **Sg** seaborgium	107 **Bh** bohrium	108 **Hs** hassium	109 **Mt** meitnerium	110 **Ds** darmstadtium	111 **Rg** roentgenium	112 **Cn** copernicium		114 **Fl** flerovium		116 **Lv** livermorium		

57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	59 **Pr** praseodymium 140.9	60 **Nd** neodymium 144.2	61 **Pm** promethium 144.9	62 **Sm** samarium 150.4	63 **Eu** europium 152.0	64 **Gd** gadolinium 157.2	65 **Tb** terbium 158.9	66 **Dy** dysprosium 162.5	67 **Ho** holmium 164.9	68 **Er** erbium 167.3	69 **Tm** thulium 168.9	70 **Yb** ytterbium 173.0	71 **Lu** lutetium 175.0
89 **Ac** actinium	90 **Th** thorium 232.0	91 **Pa** protactinium	92 **U** uranium 238.1	93 **Np** neptunium	94 **Pu** plutonium	95 **Am** americium	96 **Cm** curium	97 **Bk** berkelium	98 **Cf** californium	99 **Es** einsteinium	100 **Fm** fermium	101 **Md** mendelevium	102 **No** nobelium	103 **Lr** lawrencium