

**40** Chromatography is used to separate and analyse mixtures of soluble substances.

The first steps of the process are listed.

- apply sample to baseline
- develop chromatogram in solvent

What is the next step in the process to detect soluble **colourless** substances?

- A** calculate the  $R_f$  values
- B** compare the results with known substances
- C** count the number of spots
- D** use a suitable locating agent



**40** A colourless mixture is separated by paper chromatography.

The steps below describe the method. These steps are **not** in the correct order.

- 1 Remove the chromatography paper from the solvent when the solvent front is near the top of the paper.
- 2 Place the chromatography paper in the solvent.
- 3 Spray the chromatography paper with a locating agent.
- 4 Place a spot of the mixture on the pencil line.
- 5 Draw a pencil line at the bottom of the chromatography paper.
- 6 Draw a pencil line to mark the position of the solvent front.

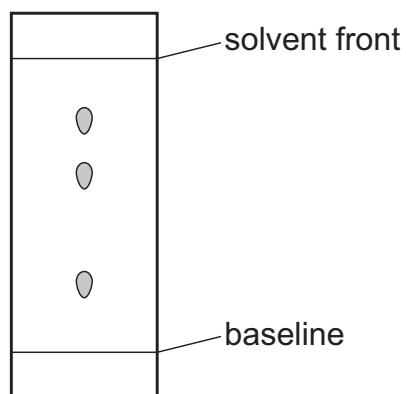
What is the correct order for these steps?

- A** 3 → 5 → 6 → 4 → 2 → 1
- B** 5 → 4 → 3 → 2 → 1 → 6
- C** 3 → 5 → 4 → 1 → 2 → 6
- D** 5 → 4 → 2 → 1 → 6 → 3



**40** A mixture of four different colourless amino acids is analysed by paper chromatography.

The final chromatogram is shown.



Why does the chromatogram only show three spots?

- A** A locating agent is **not** used.
- B** One of the amino acids is insoluble in the solvent.
- C** The solvent front is too near the top of the paper.
- D** Two of the amino acids have the same  $R_f$  value.

The Periodic Table of Elements

| Group                                |                                       |                                                                                            |                                      |                                     |                                        |                                      |                              |                                      |                                |                                     |                               |                                      |                                       |                                       |                                      |                                     |                                      |                        |
|--------------------------------------|---------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------|-------------------------------------|----------------------------------------|--------------------------------------|------------------------------|--------------------------------------|--------------------------------|-------------------------------------|-------------------------------|--------------------------------------|---------------------------------------|---------------------------------------|--------------------------------------|-------------------------------------|--------------------------------------|------------------------|
| I                                    | II                                    |                                                                                            |                                      |                                     |                                        |                                      |                              |                                      |                                |                                     |                               | III                                  | IV                                    | V                                     | VI                                   | VII                                 | VIII                                 |                        |
|                                      |                                       | <div>1<div>Hhydrogen1</div></div>                                                          |                                      |                                     |                                        |                                      |                              |                                      |                                |                                     |                               |                                      |                                       |                                       |                                      |                                     |                                      | 2 <div>Hehelium4</div> |
|                                      |                                       | <div>Key<div>atomic number<br/>atomic symbol<br/>name<br/>relative atomic mass</div></div> |                                      |                                     |                                        |                                      |                              |                                      |                                |                                     |                               |                                      |                                       |                                       |                                      |                                     |                                      |                        |
| 3 <div>Li<br/>lithium<br/>7</div>    | 4 <div>Be<br/>beryllium<br/>9</div>   |                                                                                            |                                      |                                     |                                        |                                      |                              |                                      |                                |                                     |                               | 5 <div>Bboron11</div>                | 6 <div>Ccarbon12</div>                | 7 <div>Nnitrogen14</div>              | 8 <div>Ooxygen16</div>               | 9 <div>Ffluorine19</div>            | 10 <div>Neonon20</div>               |                        |
| 11 <div>Na<br/>sodium<br/>23</div>   | 12 <div>Mg<br/>magnesium<br/>24</div> |                                                                                            |                                      |                                     |                                        |                                      |                              |                                      |                                |                                     |                               | 13 <div>Alaluminium27</div>          | 14 <div>Si<br/>silicon<br/>28</div>   | 15 <div>Pphosphorus31</div>           | 16 <div>Ssulfur32</div>              | 17 <div>Clchlorine35.5</div>        | 18 <div>Ar<br/>argon<br/>40</div>    |                        |
| 19 <div>K<br/>potassium<br/>39</div> | 20 <div>Ca<br/>calcium<br/>40</div>   | 21 <div>Sc<br/>scandium<br/>45</div>                                                       | 22 <div>Ti<br/>titanium<br/>48</div> | 23 <div>V<br/>vanadium<br/>51</div> | 24 <div>Cr<br/>chromium<br/>52</div>   | 25 <div>Mnmanganese55</div>          | 26 <div>Feiron56</div>       | 27 <div>Co<br/>cobalt<br/>59</div>   | 28 <div>Ninickel59</div>       | 29 <div>Cucopper64</div>            | 30 <div>Znzinc65</div>        | 31 <div>Gagallium70</div>            | 32 <div>Ge<br/>germanium<br/>73</div> | 33 <div>As<br/>arsenic<br/>75</div>   | 34 <div>Se<br/>selenium<br/>79</div> | 35 <div>Br<br/>bromine<br/>80</div> | 36 <div>Krkrypton84</div>            |                        |
| 37 <div>Rb<br/>rubidium<br/>85</div> | 38 <div>Sr<br/>strontium<br/>88</div> | 39 <div>Y<br/>yttrium<br/>89</div>                                                         | 40 <div>Zrzirconium91</div>          | 41 <div>Nbniobium93</div>           | 42 <div>Mo<br/>molybdenum<br/>96</div> | 43 <div>Tctechnetium—</div>          | 44 <div>Ruruthenium101</div> | 45 <div>Rhrhodium103</div>           | 46 <div>Pdpalladium106</div>   | 47 <div>Ag<br/>silver<br/>108</div> | 48 <div>Cdcadmium112</div>    | 49 <div>Inindium115</div>            | 50 <div>Sn<br/>tin<br/>119</div>      | 51 <div>Sb<br/>antimony<br/>122</div> | 52 <div>Tetellurium128</div>         | 53 <div>I<br/>iodine<br/>127</div>  | 54 <div>Xexenon131</div>             |                        |
| 55 <div>Cs<br/>caesium<br/>133</div> | 56 <div>Ba<br/>barium<br/>137</div>   | 57–71 <div>lanthanoids</div>                                                               | 72 <div>Hfhafnium178</div>           | 73 <div>Tatantalum181</div>         | 74 <div>Wtungsten184</div>             | 75 <div>Re<br/>rhenium<br/>186</div> | 76 <div>Ososmium190</div>    | 77 <div>Ir<br/>iridium<br/>192</div> | 78 <div>Ptplatinum195</div>    | 79 <div>Augold197</div>             | 80 <div>Hgmercury201</div>    | 81 <div>Tlthallium204</div>          | 82 <div>Pb<br/>lead<br/>207</div>     | 83 <div>Bibismuth209</div>            | 84 <div>Popolonium—</div>            | 85 <div>At<br/>astatine<br/>—</div> | 86 <div>Rnradon—</div>               |                        |
| 87 <div>Fr<br/>francium<br/>—</div>  | 88 <div>Ra<br/>radium<br/>—</div>     | 89–103 <div>actinoids</div>                                                                | 104 <div>Rfrutherfordium—</div>      | 105 <div>Dbdubnium—</div>           | 106 <div>Sgseaborgium—</div>           | 107 <div>Bhbohrium—</div>            | 108 <div>Hshassium—</div>    | 109 <div>Mtmeitnerium—</div>         | 110 <div>Dsdarmstadtium—</div> | 111 <div>Rgroentgenium—</div>       | 112 <div>Cncopernicium—</div> | 113 <div>Nh<br/>nihonium<br/>—</div> | 114 <div>Fl<br/>flerovium<br/>—</div> | 115 <div>Mc<br/>moscovium<br/>—</div> | 116 <div>Lvlivermorium—</div>        | 117 <div>Tstemessine—</div>         | 118 <div>Og<br/>oganeson<br/>—</div> |                        |

|             |                                        |                                      |                                           |                                        |                                       |                                       |                                       |                                         |                                      |                                         |                                        |                                        |
|-------------|----------------------------------------|--------------------------------------|-------------------------------------------|----------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|-----------------------------------------|--------------------------------------|-----------------------------------------|----------------------------------------|----------------------------------------|
| lanthanoids | 57 <div>La<br/>lanthanum<br/>139</div> | 58 <div>Ce<br/>cerium<br/>140</div>  | 59 <div>Pr<br/>praseodymium<br/>141</div> | 60 <div>Nd<br/>neodymium<br/>144</div> | 61 <div>Pm<br/>promethium<br/>—</div> | 62 <div>Sm<br/>samarium<br/>150</div> | 63 <div>Eu<br/>europium<br/>152</div> | 64 <div>Gd<br/>gadolinium<br/>157</div> | 65 <div>Tb<br/>terbium<br/>159</div> | 66 <div>Dy<br/>dysprosium<br/>163</div> | 67 <div>Ho<br/>holmium<br/>165</div>   | 71 <div>Lu<br/>lutetium<br/>175</div>  |
|             | 89 <div>Ac<br/>actinium<br/>—</div>    | 90 <div>Th<br/>thorium<br/>232</div> | 91 <div>Pa<br/>protactinium<br/>231</div> | 92 <div>U<br/>uranium<br/>238</div>    | 93 <div>Np<br/>neptunium<br/>—</div>  | 94 <div>Pu<br/>plutonium<br/>—</div>  | 95 <div>Am<br/>americium<br/>—</div>  | 96 <div>Cm<br/>curium<br/>—</div>       | 97 <div>Bk<br/>berkelium<br/>—</div> | 98 <div>Cf<br/>californium<br/>—</div>  | 99 <div>Es<br/>einsteinium<br/>—</div> | 103 <div>Lr<br/>lawrencium<br/>—</div> |

The volume of one mole of any gas is 24 dm<sup>3</sup> at room temperature and pressure (r.t.p.).

**40** In paper chromatography, what is the equation for the  $R_f$  value?

**A**  $R_f = \frac{\text{distance travelled by solvent}}{\text{distance travelled by substance}}$

**B**  $R_f = \frac{\text{distance travelled by locating agent}}{\text{distance travelled by substance}}$

**C**  $R_f = \frac{\text{distance travelled by substance}}{\text{distance travelled by locating agent}}$

**D**  $R_f = \frac{\text{distance travelled by substance}}{\text{distance travelled by solvent}}$



- 40** A mixture of soluble substances can be separated by paper chromatography. Each substance can be identified using its  $R_f$  value.

Which formula shows how the  $R_f$  value is calculated?

- A**  $R_f = \frac{\text{distance travelled by solvent}}{\text{distance travelled by substance}}$
- B**  $R_f = \frac{\text{distance travelled by substance}}{\text{distance travelled by solvent}}$
- C**  $R_f = \text{distance travelled by solvent} - \text{distance travelled by substance}$
- D**  $R_f = \text{distance travelled by solvent} \times \text{distance travelled by substance}$

The Periodic Table of Elements

| Group                      |                             |                                                                                             |                                 |                             |                              |                             |                              |                              |                                |                               |                               |                             |                             |                             |                               |                              |                            |  |
|----------------------------|-----------------------------|---------------------------------------------------------------------------------------------|---------------------------------|-----------------------------|------------------------------|-----------------------------|------------------------------|------------------------------|--------------------------------|-------------------------------|-------------------------------|-----------------------------|-----------------------------|-----------------------------|-------------------------------|------------------------------|----------------------------|--|
| I                          | II                          |                                                                                             |                                 |                             |                              |                             |                              |                              |                                |                               |                               | III                         | IV                          | V                           | VI                            | VII                          | VIII                       |  |
|                            |                             | <div>Key</div> <div>atomic number<br/>atomic symbol<br/>name<br/>relative atomic mass</div> |                                 |                             |                              |                             |                              |                              |                                |                               |                               |                             |                             |                             |                               |                              |                            |  |
| 3<br>Li<br>lithium<br>7    | 4<br>Be<br>beryllium<br>9   |                                                                                             |                                 |                             |                              |                             |                              |                              |                                |                               |                               | 1<br>H<br>hydrogen<br>1     |                             |                             |                               |                              |                            |  |
| 11<br>Na<br>sodium<br>23   | 12<br>Mg<br>magnesium<br>24 |                                                                                             |                                 |                             |                              |                             |                              |                              |                                |                               |                               |                             |                             |                             |                               |                              |                            |  |
| 19<br>K<br>potassium<br>39 | 20<br>Ca<br>calcium<br>40   | 21<br>Sc<br>scandium<br>45                                                                  | 22<br>Ti<br>titanium<br>48      | 23<br>V<br>vanadium<br>51   | 24<br>Cr<br>chromium<br>52   | 25<br>Mn<br>manganese<br>55 | 26<br>Fe<br>iron<br>56       | 27<br>Co<br>cobalt<br>59     | 28<br>Ni<br>nickel<br>59       | 29<br>Cu<br>copper<br>64      | 30<br>Zn<br>zinc<br>65        | 31<br>Ga<br>gallium<br>70   | 32<br>Ge<br>germanium<br>73 | 33<br>As<br>arsenic<br>75   | 34<br>Se<br>selenium<br>79    | 35<br>Br<br>bromine<br>80    | 36<br>Kr<br>krypton<br>84  |  |
| 37<br>Rb<br>rubidium<br>85 | 38<br>Sr<br>strontium<br>88 | 39<br>Y<br>yttrium<br>89                                                                    | 40<br>Zr<br>zirconium<br>91     | 41<br>Nb<br>niobium<br>93   | 42<br>Mo<br>molybdenum<br>96 | 43<br>Tc<br>technetium<br>— | 44<br>Ru<br>ruthenium<br>101 | 45<br>Rh<br>rhodium<br>103   | 46<br>Pd<br>palladium<br>106   | 47<br>Ag<br>silver<br>108     | 48<br>Cd<br>cadmium<br>112    | 49<br>In<br>indium<br>115   | 50<br>Sn<br>tin<br>119      | 51<br>Sb<br>antimony<br>122 | 52<br>Te<br>tellurium<br>128  | 53<br>I<br>iodine<br>127     | 54<br>Xe<br>xenon<br>131   |  |
| 55<br>Cs<br>caesium<br>133 | 56<br>Ba<br>barium<br>137   | 57–71<br>lanthanoids                                                                        | 72<br>Hf<br>hafnium<br>178      | 73<br>Ta<br>tantalum<br>181 | 74<br>W<br>tungsten<br>184   | 75<br>Re<br>rhenium<br>186  | 76<br>Os<br>osmium<br>190    | 77<br>Ir<br>iridium<br>192   | 78<br>Pt<br>platinum<br>195    | 79<br>Au<br>gold<br>197       | 80<br>Hg<br>mercury<br>201    | 81<br>Tl<br>thallium<br>204 | 82<br>Pb<br>lead<br>207     | 83<br>Bi<br>bismuth<br>209  | 84<br>Po<br>polonium<br>—     | 85<br>At<br>astatine<br>—    | 86<br>Rn<br>radon<br>—     |  |
| 87<br>Fr<br>francium<br>—  | 88<br>Ra<br>radium<br>—     | 89–103<br>actinoids                                                                         | 104<br>Rf<br>rutherfordium<br>— | 105<br>Db<br>dubnium<br>—   | 106<br>Sg<br>seaborgium<br>— | 107<br>Bh<br>bohrium<br>—   | 108<br>Hs<br>hassium<br>—    | 109<br>Mt<br>meitnerium<br>— | 110<br>Ds<br>darmstadtium<br>— | 111<br>Rg<br>roentgenium<br>— | 112<br>Cn<br>copernicium<br>— | 113<br>Nh<br>nihonium<br>—  | 114<br>Fl<br>flerovium<br>— | 115<br>Mc<br>moscovium<br>— | 116<br>Lv<br>livermorium<br>— | 117<br>Ts<br>tennessine<br>— | 118<br>Og<br>oganeson<br>— |  |

|             |                              |                            |                                 |                              |                             |                             |                             |                               |                            |                               |                              |                           |                               |                              |                              |
|-------------|------------------------------|----------------------------|---------------------------------|------------------------------|-----------------------------|-----------------------------|-----------------------------|-------------------------------|----------------------------|-------------------------------|------------------------------|---------------------------|-------------------------------|------------------------------|------------------------------|
| lanthanoids | 57<br>La<br>lanthanum<br>139 | 58<br>Ce<br>cerium<br>140  | 59<br>Pr<br>praseodymium<br>141 | 60<br>Nd<br>neodymium<br>144 | 61<br>Pm<br>promethium<br>— | 62<br>Sm<br>samarium<br>150 | 63<br>Eu<br>europium<br>152 | 64<br>Gd<br>gadolinium<br>157 | 65<br>Tb<br>terbium<br>159 | 66<br>Dy<br>dysprosium<br>163 | 67<br>Ho<br>holmium<br>165   | 68<br>Er<br>erbium<br>167 | 69<br>Tm<br>thulium<br>169    | 70<br>Yb<br>ytterbium<br>173 | 71<br>Lu<br>lutetium<br>175  |
|             | 89<br>Ac<br>actinium<br>—    | 90<br>Th<br>thorium<br>232 | 91<br>Pa<br>protactinium<br>231 | 92<br>U<br>uranium<br>238    | 93<br>Np<br>neptunium<br>—  | 94<br>Pu<br>plutonium<br>—  | 95<br>Am<br>americium<br>—  | 96<br>Cm<br>curium<br>—       | 97<br>Bk<br>berkelium<br>— | 98<br>Cf<br>californium<br>—  | 99<br>Es<br>einsteinium<br>— | 100<br>Fm<br>fermium<br>— | 101<br>Md<br>mendelevium<br>— | 102<br>No<br>nobelium<br>—   | 103<br>Lr<br>lawrencium<br>— |

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