

Past-paper walk-through

Chromatography ■ 12.3

eXercise

Questions in this set

- 0620/22 N25 Q40 ■ 1 mark
- 0620/23 N25 Q40 ■ 1 mark
- 0620/21 J25 Q40 ■ 1 mark
- 0620/23 J25 Q40 ■ 1 mark
- 0620/22 M25 Q40 ■ 1 mark

Question 40

0620/22 N25 ■ Q40 ■ 1 mark

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

Question 40

III	IV	V	VI	VII	VIII
					2 He helium 4
5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium —	85 At astatine —	86 Rn radon —
113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganesson —

67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
99 Es einsteinium —	100 Fm fermium —	101 Md mendelevium —	102 No nobelium —	103 Lr lawrencium —

The Periodic Table of Elements

Group											
1 H hydrogen 1											
25	Mn	26	Fe	27	Co	28	Ni	29	Cu	30	Zn
ngnese	iron	56	cobalt	59	nickel	59	copper	64	zinc	65	
43	Tc	44	Ru	45	Rh	46	Pd	47	Ag	48	Cd
hnetium	ruthenium	101	rhodium	103	palladium	106	silver	108	cadmium	112	
75	Re	76	Os	77	Ir	78	Pt	79	Au	80	Hg
tenium	osmium	190	iridium	192	platinum	195	gold	197	mercury	201	
107	Bh	108	Hs	109	Mt	110	Ds	111	Rg	112	Cn
ohrium	hassium	–	meitnerium	–	darmstadtium	–	roentgenium	–	copernicium	–	
61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy
methium	samarium	150	euporium	152	gadolinium	157	terbium	159	dysprosium	163	
93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf
plutonium	plutonium	–	americium	–	curium	–	berkelium	–	californium	–	

perature and pressure (r.t.p.).

	II

Key		
atomic number		
atomic symbol		
name		
relative atomic mass		

n	4 Be beryllium 9				
im	12 Mg magnesium 24				
um	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52
im	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96
im	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184
im	88 Ra radium —	89–103 actinoids	104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —

anoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	I pro
oids	89 Ac actinium —	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	nei

volume of one mole of any gas is 24 dm³ at room tem

Question 40

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3 Li 7 11 19 23 39 47 55 63 71 79 87 95 103 111 119 127 135 143 151 159 167 175 183 191 199 207 215 223 231 239 247 255 263 271 279 287 295 303 311 319 327 335 343 351 359 367 375 383 391 399 407 415 423 431 439 447 455 463 471 479 487 495 503 511 519 527 535 543 551 559 567 575 583 591 599 607 615 623 631 639 647 655 663 671 679 687 695 703 711 719 727 735 743 751 759 767 775 783 791 799 807 815 823 831 839 847 855 863 871 879 887 895 903 911 919 927 935 943 951 959 967 975 983 991 999

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Question 40

			I lit	N so		pota	F rub	C ca	1	F fr
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Solution 40

Answer: **D**

Why

- The paper must be taken out before the solvent runs off the top.
- Mark the solvent front straight away, while it is still visible.
- Only then can the distances – and so the R_f values – be measured.

Question 40

0620/23 N25 ■ Q40 ■ 1 mark

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?

Question 40

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

	VI	VII	VIII
			2 He helium 4
1 H hydrogen	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
2 He helium	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
3 Li lithium	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
4 Be beryllium	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
5 B boron	84 Po polonium —	85 At astatine —	86 Rn radon —
6 C carbon	116 Lv livermorium —	117 Ts tennessine —	118 Og oganesson —

70 Yb ytterbium 173	71 Lu lutetium 175
102 No nobelium —	103 Lr lawrencium —

Table of Elements

Group	III	IV	V
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	28	29	30	5	6	7
	Ni nickel 59	Cu copper 64	Zn zinc 65	B boron 11	C carbon 12	N nitrogen 14
	46	47	48	13	14	15
	Pd palladium 106	Ag silver 108	Cd cadmium 112	Al aluminum 27	Si silicon 28	P phosphorus 31
n	78	79	80	31	32	33
	Pt platinum 195	Au gold 197	Hg mercury 201	Ga gallium 70	Ge germanium 73	As arsenic 75
i	110	111	112	49	50	51
	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	In indium 115	Sn tin 119	Sb antimony 121
um	114	115	116	81	82	83
	Fl flerovium —	Mc moscovium —	Lv livermorium —	Tl thallium 204	Pb lead 207	Bi bismuth 209

64	65	66	67	68	69
Gd gadolinium 157	Tb terbium 159	Dy dysprosium 163	Ho holmium 165	Er erbium 167	Tm thulium 169
96	97	98	99	100	101
Cm curium —	Bk berkelium —	Cf californium —	Es einsteinium —	Fm fermium —	M mendelevium —

 ε (r.t.p.).

Question 40

The Periodic

1	H hydrogen 1

Key

atomic number
atomic symbol
name
relative atomic mass

22	Ti	titanium	48	23	V	vanadium	51	24	Cr	chromium	52	25	Mn	manganese	55	26	Fe	iron	56	27	Co	cobalt	59
40	Zr	zirconium	91	41	Nb	niobium	93	42	Mo	molybdenum	96	43	Tc	technetium	–	44	Ru	ruthenium	101	45	Rh	rhodium	103
72	Hf	hafnium	178	73	Ta	tantalum	181	74	W	tungsten	184	75	Re	rhenium	186	76	Os	osmium	190	77	Ir	iridium	192
104	Rf	rutherfordium	–	105	Db	dubnium	–	106	Sg	seaborgium	–	107	Bh	bohrium	–	108	Hs	hassium	–	109	Mt	meitnerium	–

58	Ce	cerium	140	59	Pr	praseodymium	141	60	Nd	neodymium	144	61	Pm	promethium	–	62	Sm	samarium	150	63	Eu	euroium	152
90	Th	thorium	232	91	Pa	protactinium	231	92	U	uranium	238	93	Np	neptunium	–	94	Pu	plutonium	–	95	Am	americium	–

any gas is 24 dm³ at room temperature and pressure

Question 40

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Question 40

I	II		
3 Li lithium 7	4 Be beryllium 9		
11 Na sodium 23	12 Mg magnesium 24		
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoid	
87 Fr francium –	88 Ra radium –	89–103 actinoids	

lanthanoids	57 La lanthanum 139
actinoids	89 Ac actinium –

The volume of one mole

Solution 40

Answer: **D**

Why

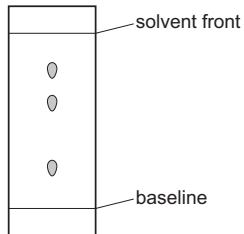
- Apply the sample to the baseline, which must sit above the solvent level so the spot is not washed off.
- Stand the paper in the solvent and let the front travel up.
- Take the paper out before the solvent reaches the top, mark the front, then use a locating agent for colourless spots.

Question 40

0620/21 J25 ■ Q40 ■ 1 mark

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?

Question 40

- 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.

/	VI	VII	VIII
2 He helium 4			
8 O oxygen 16	9 F fluorine 19	10 Ne neon 20	
16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40	
34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84	
52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131	
84 Po polonium -	85 At astatine -	86 Rn radon -	
116 Lv livermorium -	117 Ts tennessine -	118 Og oganeson -	

70 Yb ytterbium 173	71 Lu lutetium 175
102 No nobelium -	103 Lr lawrencium -

Question 40

Table of Elements

Group				
		III	IV	V

13	Al	Aluminum 13	Si	Silicon 14	P	Phosphorus 15
14	Ge	Germanium 32	As	Arsenic 33	Se	Selenium 34
15	Sb	Antimony 51	Te	Tellurium 52	I	Iodine 53
16	Po	Polonium 84	At	Astatine 85	Rn	Radon 86

17	Br	Bromine 35	Kr	Krypton 36	Xe	Xenon 54
18	Pt	Platinum 78	Au	Gold 79	Hg	Mercury 80
19	Cu	Copper 29	Zn	Zinc 30	Ga	Gallium 31
20	Ni	Nickel 28	Pd	Palladium 46	Ag	Silver 47

re (r.t.p.).

The Periodic

1	H	hydrogen	1
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Key

atomic number
atomic symbol
name
relative atomic mass

22	Ti	titanium	48	23	V	vanadium	51	24	Cr	chromium	52	25	Mn	manganese	55	26	Fe	iron	56	27	Co	cobalt	59
40	Zr	zirconium	91	41	Nb	niobium	93	42	Mo	molybdenum	96	43	Tc	technetium	—	44	Ru	ruthenium	101	45	Rh	rhodium	103
72	Hf	hafnium	178	73	Ta	tantalum	181	74	W	tungsten	184	75	Re	rhenium	186	76	Os	osmium	190	77	Ir	iridium	192
104	Rf	rutherfordium	—	105	Db	dubnium	—	106	Sg	seaborgium	—	107	Bh	bohrium	—	108	Hs	hassium	—	109	Mt	meitnerium	—

58	Ce	cerium	140	59	Pr	praseodymium	141	60	Nd	neodymium	144	61	Pm	promethium	—	62	Sm	samarium	150	63	Eu	euporium	152
90	Th	thorium	232	91	Pa	protactinium	231	92	U	uranium	238	93	Np	neptunium	—	94	Pu	plutonium	—	95	Am	americium	—

Volume of any gas is 24 dm³ at room temperature and pressure

Question 40

I	II	
3 Li lithium 7	4 Be beryllium 9	
11 Na sodium 23	12 Mg magnesium 24	
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89
55 Cs caesium 133	56 Ba barium 137	57-70 lanthanoids
87 Fr francium —	88 Ra radium —	89-103 actinoids

lanthanoids

57	La lanthanum	139
89	Ac actinium	—

actinoids

The volume of one mole

Solution 40

Answer: **D**

Why

- A locating agent is what makes colourless spots visible, so its absence would give *no* spots.
- Four substances should give four spots unless two travelled exactly the same distance.
- Two amino acids with the same R_f overlap into a single spot.

Question 40

0620/23 J25 ■ Q40 ■ 1 mark

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

Question 40

III	IV	V	VI	VII	VIII
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57 La lanthanum 139	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
89 Ac actinium —	100 Fm fermium —	101 Md mendelevium —	102 No nobelium —	103 Lr lawrencium —

The Periodic Table of Elements

[illegible]

ature and pressure (r.t.p.).

II	
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Key
atomic number
atomic symbol
name
relative atomic mass

atomic number atomic symbol name relative atomic mass					
4 Be beryllium 9					
12 Mg magnesium 24					
20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55
38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium —
56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186
88 Ra radium —	89–103 actinoids	104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —

ids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium —
;	89 Ac actinium —	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium —

me of one mole of any gas is 24 dm³ at room temper

Question 40

[illegible]

lanthano

actinoids

The volu

Solution 40

Answer: **D**

Why

- R_f compares the distance the spot moved with the distance the solvent moved.
- So it is distance travelled by the substance divided by distance travelled by the solvent.
- The locating agent only makes the spots visible; it plays no part in the calculation.

Question 40

0620/22 M25 ■ Q40 ■ 1 mark

- 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 $R_f = \text{distance travelled by solvent} \times \text{distance travelled by substance}$

Question 40

III	IV	V	VI	VII	VIII
					2 He helium 4
5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
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67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
99 Es einsteinium —	100 Fm fermium —	101 Md mendelevium —	102 No nobelium —	103 Lr lawrencium —

The Periodic Table of Elements

Group

$$\begin{array}{|c|c|c|} \hline & \text{hydrogen} & \\ \hline 1 & \text{H} & 1 \\ \hline \end{array}$$

25	Vn	26	Fe	27	Co	28	Ni	29	Cu	30	Zn
vanadium	iron	cobalt	nickel	copper	zinc						
55	56	59	58	63	65						
43	44	45	46	47	48						
Tc	Ru	Rh	Pd	Ag	Cd						
technetium	ruthenium	rhodium	palladium	silver	cadmium						
—	101	103	106	108	112						
75	76	77	78	79	80						
Re	Os	Ir	Pt	Au	Hg						
rhodium	osmium	iridium	platinum	gold	mercury						
186	190	192	195	197	201						
107	108	109	110	111	112						
Bh	Hs	Mt	Ds	Rg	Cn						
bohrium	hassium	meitnerium	darmstadtium	roentgenium	copernicium						
—	—	—	—	—	—						

61	62	63	64	65	66
Pm methylum —	Sm samarium 150	Eu europium 152	Gd gadolinium 157	Tb terbium 159	Dy dysprosium 163
93	94	95	96	97	98
Np neptunium —	Pu plutonium —	Am americium —	Cm curium —	Bk berkelium —	Cf californium —

perature and pressure (r.t.p.).

[illegible]

		Key			
		atomic number	atomic symbol	name	relative atomic mass
3	Li lithium 7	4	Be beryllium 9		
11	Na sodium 23	12	Mg magnesium 24		
19	K potassium 39	20	Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48
37	Rb rubidium 85	38	Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91
55	Cs cesium 133	56	Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178
87	Fr francium 223	88	Ra radium 226	89–103 actinoids	104 Rf rutherfordium 261
93	Np neptunium 237	94	Pl plutonium 244	95–100 transactinoids	101 Db dubnium 268
101	Db dubnium 262	102	Lr lawrencium 260	103–118 superheavy elements	104 Rf rutherfordium 261
109	Th thorium 232	110	Ds darmstadtium 271	111–116 superheavy elements	112 Cn copernicium 285
115	Mc moscovium 288	116	Lv livermorium 293	117–118 superheavy elements	118 Og oganesson 294
117	Ts tennessine 294	118	Ug unbinilium 297	119–120 superheavy elements	120 Ubn unbinilium 298
120	Ubn unbinilium 304	121	Uut ununilium 304	122–123 superheavy elements	123 Uub ununilium 307
122	Uuq unquencium 311	123	Uub ununilium 311	124–125 superheavy elements	125 Uut ununilium 312
124	Uuh unhexium 315	125	Uus ununseptium 315	126–127 superheavy elements	127 Uut ununilium 318
126	Uuo ununoctium 317	127	Uus ununseptium 317	128–129 superheavy elements	129 Uut ununilium 320
128	Uuo ununoctium 319	129	Uus ununseptium 319	130–131 superheavy elements	131 Uut ununilium 322
130	Uuo ununoctium 321	131	Uus ununseptium 321	132–133 superheavy elements	133 Uut ununilium 324
132	Uuo ununoctium 323	133	Uus ununseptium 323	134–135 superheavy elements	135 Uut ununilium 326
134	Uuo ununoctium 325	135	Uus ununseptium 325	136–137 superheavy elements	137 Uut ununilium 328
136	Uuo ununoctium 327	137	Uus ununseptium 327	138–139 superheavy elements	139 Uut ununilium 330
138	Uuo ununoctium 329	139	Uus ununseptium 329	140–141 superheavy elements	141 Uut ununilium 332
140	Uuo ununoctium 331	141	Uus ununseptium 331	142–143 superheavy elements	143 Uut ununilium 334
142	Uuo ununoctium 333	143	Uus ununseptium 333	144–145 superheavy elements	145 Uut ununilium 336
144	Uuo ununoctium 335	145	Uus ununseptium 335	146–147 superheavy elements	147 Uut ununilium 338
146	Uuo ununoctium 337	147	Uus ununseptium 337	148–149 superheavy elements	149 Uut ununilium 340
148	Uuo ununoctium 339	149	Uus ununseptium 339	150–151 superheavy elements	151 Uut ununilium 342
150	Uuo ununoctium 341	151	Uus ununseptium 341	152–153 superheavy elements	153 Uut ununilium 344
152	Uuo ununoctium 343	153	Uus ununseptium 343	154–155 superheavy elements	155 Uut ununilium 346
154	Uuo ununoctium 345	155	Uus ununseptium 345	156–157 superheavy elements	157 Uut ununilium 348
156	Uuo ununoctium 347	157	Uus ununseptium 347	158–159 superheavy elements	159 Uut ununilium 350
158	Uuo ununoctium 349	159	Uus ununseptium 349	160–161 superheavy elements	161 Uut ununilium 352
160	Uuo ununoctium 351	161	Uus ununseptium 351	162–163 superheavy elements	163 Uut ununilium 354
162	Uuo ununoctium 353	163	Uus ununseptium 353	164–165 superheavy elements	165 Uut ununilium 356
164	Uuo ununoctium 355	165	Uus ununseptium 355	166–167 superheavy elements	167 Uut ununilium 358
166	Uuo ununoctium 357	167	Uus ununseptium 357	168–169 superheavy elements	169 Uut ununilium 360
168	Uuo ununoctium 359	169	Uus ununseptium 359	170–171 superheavy elements	171 Uut ununilium 362
170	Uuo ununoctium 361	171	Uus ununseptium 361	172–173 superheavy elements	173 Uut ununilium 364
172	Uuo ununoctium 363	173	Uus ununseptium 363	174–175 superheavy elements	175 Uut ununilium 366
174	Uuo ununoctium 365	175	Uus ununseptium 365	176–177 superheavy elements	177 Uut ununilium 368
176	Uuo ununoctium 367	177	Uus ununseptium 367	178–179 superheavy elements	179 Uut ununilium 370
178	Uuo ununoctium 369	179	Uus ununseptium 369	180–181 superheavy elements	181 Uut ununilium 372
180	Uuo ununoctium 371	181	Uus ununseptium 371	182–183 superheavy elements	183 Uut ununilium 374
182	Uuo ununoctium 373	183	Uus ununseptium 373	184–185 superheavy elements	185 Uut ununilium 376
184	Uuo ununoctium 375	185	Uus ununseptium 375	186–187 superheavy elements	187 Uut ununilium 378
186	Uuo ununoctium 377	187	Uus ununseptium 377	188–189 superheavy elements	189 Uut ununilium 380
188	Uuo ununoctium 379	189	Uus ununseptium 379	190–191 superheavy elements	191 Uut ununilium 382
190	Uuo ununoctium 381	191	Uus ununseptium 381	192–193 superheavy elements	193 Uut ununilium 384
192	Uuo ununoctium 383	193	Uus ununseptium 383	194–195 superheavy elements	195 Uut ununilium 386
194	Uuo ununoctium 385	195	Uus ununseptium 385	196–197 superheavy elements	197 Uut ununilium 388
196	Uuo ununoctium 387	197	Uus ununseptium 387	198–199 superheavy elements	199 Uut ununilium 390
198	Uuo ununoctium 389	199	Uus ununseptium 389	200–201 superheavy elements	201 Uut ununilium 392
200	Uuo ununoctium 391	201	Uus ununseptium 391	202–203 superheavy elements	203 Uut ununilium 394
202	Uuo ununoctium 393	203	Uus ununseptium 393	204–205 superheavy elements	205 Uut ununilium 396
204	Uuo ununoctium 395	205	Uus ununseptium 395	206–207 superheavy elements	207 Uut ununilium 398
206	Uuo ununoctium 397	207	Uus ununseptium 397	208–209 superheavy elements	209 Uut ununilium 400
208	Uuo ununoctium 399	209	Uus ununseptium 399	210–211 superheavy elements	211 Uut ununilium 402
210	Uuo ununoctium 401	211	Uus ununseptium 401	212–213 superheavy elements	213 Uut ununilium 404
212	Uuo ununoctium 403	213	Uus ununseptium 403	214–215 superheavy elements	215 Uut ununilium 406
214	Uuo ununoctium 405	215	Uus ununseptium 405	216–217 superheavy elements	217 Uut ununilium 408
216	Uuo ununoctium 407	217	Uus ununseptium 407	218–219 superheavy elements	219 Uut ununilium 410
218	Uuo ununoctium 409	219	Uus ununseptium 409	220–221 superheavy elements	221 Uut ununilium 412
220	Uuo ununoctium 411	221	Uus ununseptium 411	222–223 superheavy elements	223 Uut ununilium 414
222	Uuo ununoctium 413	223	Uus ununseptium 413	224–225 superheavy elements	225 Uut ununilium 416
224	Uuo ununoctium 415	225	Uus ununseptium 415	226–227 superheavy elements	227 Uut ununilium 418
226	Uuo ununoctium 417	227	Uus ununseptium 417	228–229 superheavy elements	229 Uut ununilium 420
228	Uuo ununoctium 419	229	Uus ununseptium 419	230–231 superheavy elements	231 Uut ununilium 422
230	Uuo ununoctium 421	231	Uus ununseptium 421	232–233 superheavy elements	233 Uut ununilium 424
232	Uuo ununoctium 423	233	Uus ununseptium 423	234–235 superheavy elements	235 Uut ununilium 426
234	Uuo ununoctium 425	235	Uus ununseptium 425	236–237 superheavy elements	237 Uut ununilium 428
236	Uuo ununoctium 427	237	Uus ununseptium 427	238–239 superheavy elements	239 Uut ununilium 430
238	Uuo ununoctium 429	239	Uus ununseptium 429	240–241 superheavy elements	241 Uut ununilium 432
240	Uuo ununoctium 431	241	Uus ununseptium 431	242–243 superheavy elements	243 Uut ununilium 434
242	Uuo ununoctium 433	243	Uus ununseptium 433	244–245 superheavy elements	245 Uut ununilium 436
244	Uuo ununoctium 435	245	Uus ununseptium 435	246–247 superheavy elements	247 Uut ununilium 438
246	Uuo ununoctium 437	247	Uus ununseptium 437	248–249 superheavy elements	249 Uut ununilium 440
248	Uuo ununoctium 439	249	Uus ununseptium 439	250–251 superheavy elements	251 Uut ununilium 442
250	Uuo ununoctium 441	251	Uus ununseptium 441	252–253 superheavy elements	253 Uut ununilium 444
252	Uuo ununoctium 443	253	Uus ununseptium 443	254–255 superheavy elements	255 Uut ununilium 446
254	Uuo ununoctium 445	255	Uus ununseptium 445	256–257 superheavy elements	257 Uut ununilium 448
256	Uuo ununoctium 447	257	Uus ununseptium 447	258–259 superheavy elements	259 Uut ununilium 450
258	Uuo ununoctium 449	259	Uus ununseptium 449	260–261 superheavy elements	261 Uut ununilium 452
260	Uuo ununoctium 451	261	Uus ununseptium 451	262–263 superheavy elements	263 Uut ununilium 454
262	Uuo ununoctium 453	263	Uus ununseptium 453	264–265 superheavy elements	265 Uut ununilium 456
264	Uuo ununoctium 455	265	Uus ununseptium 455	266–267 superheavy elements	267 Uut ununilium 458
266	Uuo ununoctium 457	267	Uus ununseptium 457	268–269 superheavy elements	269 Uut ununilium 460
268	Uuo ununoctium 459	269	Uus ununseptium 459	270–271 superheavy elements	271 Uut ununilium 462
270	Uuo ununoctium 461	271	Uus ununseptium 461	272–273 superheavy elements	273 Uut ununilium 464
272	Uuo ununoctium 463	273	Uus ununseptium 463	274–275 superheavy elements	275 Uut ununilium 466
274	Uuo ununoctium 465	275	Uus ununseptium 465	276–277 superheavy elements	277 Uut ununilium 468
276	Uuo ununoctium 467	277	Uus ununseptium 467	278–279 superheavy elements	279 Uut ununilium 470
278	Uuo ununoctium 469	279	Uus ununseptium 469	280–281 superheavy elements	281 Uut ununilium 472
280	Uuo ununoctium 471	281	Uus ununseptium 471	282–283 superheavy elements	283 Uut ununilium 474
282	Uuo ununoctium 473	283	Uus ununseptium 473	284–285 superheavy elements	285 Uut ununilium 476
284	Uuo ununoctium 475	285	Uus ununseptium 475	286–287 superheavy elements	287 Uut ununilium 478
286	Uuo ununoctium 477	287	Uus ununseptium 477	288–289 superheavy elements	289 Uut ununilium 480
288	Uuo ununoctium 479	289	Uus ununseptium 479	290–291 superheavy elements	291 Uut ununilium 482
290	Uuo ununoctium 481	291	Uus ununseptium 481	292–293 superheavy elements	293 Uut ununilium 484
292	Uuo ununoctium 483	293	Uus ununseptium 483	294–295 superheavy elements	295 Uut ununilium 486
294	Uuo ununoctium 485	295	Uus ununseptium 485	296–297 superheavy elements	297 Uut ununilium 488
296	Uuo ununoctium 487	297	Uus ununseptium 487	298–299 superheavy elements	299 Uut ununilium 490
298	Uuo ununoctium 489	299	Uus ununseptium 489	300–301 superheavy elements	301 Uut ununilium 492
300	Uuo ununoctium 491	301	Uus ununseptium 491	302–303 superheavy elements	303 Uut ununilium 494
302	Uuo ununoctium 493	303	Uus ununseptium 493	304–305 superheavy elements	305 Uut ununilium 496
304	Uuo ununoctium 495	305	Uus ununseptium 495	306–307 superheavy elements	307 Uut ununilium 498
306	Uuo ununoctium 497	307	Uus ununseptium 497	308–309 superheavy elements	309 Uut ununilium 500
308	Uuo ununoctium 499	309	Uus ununseptium 499	310–311 superheavy elements	311 Uut ununilium 502
310	Uuo ununoctium 501	311	Uus ununseptium 501	312–313 superheavy elements	313 Uut ununilium 504
312	Uuo ununoctium 503	313	Uus ununseptium 503	314–315 superheavy elements	315 Uut ununilium 506
314	Uuo ununoctium 505	315	Uus ununseptium 505	316–317 superheavy elements	317 Uut ununilium 508
316	Uuo ununoctium 507	317	Uus ununseptium 507	318–319 superheavy elements	319 Uut ununilium 510
318	Uuo ununoctium 509	319	Uus ununseptium 509	320–321 superheavy elements	321 Uut ununilium 512
320	Uuo ununoctium 511	321	Uus ununseptium 511	322–323 superheavy elements	323 Uut ununilium 514
322	Uuo ununoctium 513	323	Uus ununseptium 513	324–325 superheavy elements	325 Uut ununilium 516
324	Uuo ununoctium 515	325	Uus ununseptium 515	326–327 superheavy elements	327 Uut ununilium 518
326	Uuo ununoctium 517	327	Uus ununseptium 517	328–329 superheavy elements	329 Uut ununilium 520
328	Uuo ununoctium 519	329	Uus ununseptium 519	330–331 superheavy elements	331 Uut ununilium 522
330	Uuo ununoctium 521	331	Uus ununseptium 521	332–333 superheavy elements	333 Uut ununilium 524
332	Uuo ununoctium 523	333	Uus ununseptium 523	334–335 superheavy elements	335 Uut ununilium 526
334	Uuo ununoctium 525	335	Uus ununseptium 525	336–337 superheavy elements	337 Uut ununilium 528
336	Uuo ununoctium 527	337	Uus ununseptium 527	338–339 superheavy elements	339 Uut ununilium 530
338	Uuo ununoctium 529	339	Uus ununseptium 529	340–341 superheavy elements	341 Uut ununilium 532
340	Uuo ununoctium 531	341	Uus ununseptium 531	342–343 superheavy elements	343 Uut ununilium 534
342	Uuo ununoctium 533	343	Uus ununseptium 533	344–345 superheavy elements	345 Uut ununilium 536
344	Uuo ununoctium 535	345	Uus ununseptium 535	346–347 superheavy elements	347 Uut ununilium 538
346	Uuo ununoctium 537	347	Uus ununseptium 537	348–349 superheavy elements	349 Uut ununilium 540
348	Uuo ununoctium 539	349	Uus ununseptium 539	350–351 superheavy elements	351 Uut ununilium 542
350	Uuo ununoctium 541	351	Uus ununseptium 541	352–353 superheavy elements	353 Uut ununilium 544
352	Uuo ununoctium 543	353	Uus ununseptium 543	354–355 superheavy elements	355 Uut ununilium 546
354	Uuo ununoctium 545	355	Uus ununseptium 545	356–357 superheavy elements	357 Uut ununilium 548
356	Uuo ununoctium 547	357	Uus ununseptium 547	358–359 superheavy elements	359 Uut ununilium 550
358	Uuo ununoctium 549	359	Uus ununseptium 549	360–361 superheavy elements	361 Uut ununilium 552
360	Uuo ununoctium 551	361	Uus ununseptium 551	362–363 superheavy elements	363 Uut ununilium 554
362	Uuo ununoctium 553	363	Uus unun		

57	58	59	60
La lanthanum 139	Ce cerium 140	Pr praseodymium 141	Nd neodymium 144
89	90	91	92
Ac actinium —	Th thorium 232	Pa protactinium 231	U uranium 238

the volume of one mole of any gas is 24 dm^3 at room temperature.

Question 40

				L lith	1 N soc	1 P potat	3 R rub	8 C cae	1. F fran
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The

Solution 40

Answer: **B**

Why

- R_f compares how far the spot moved with how far the solvent moved.
- So it is the distance travelled by the substance divided by the distance travelled by the solvent.
- That makes R_f always less than 1.