Student Pack KS4

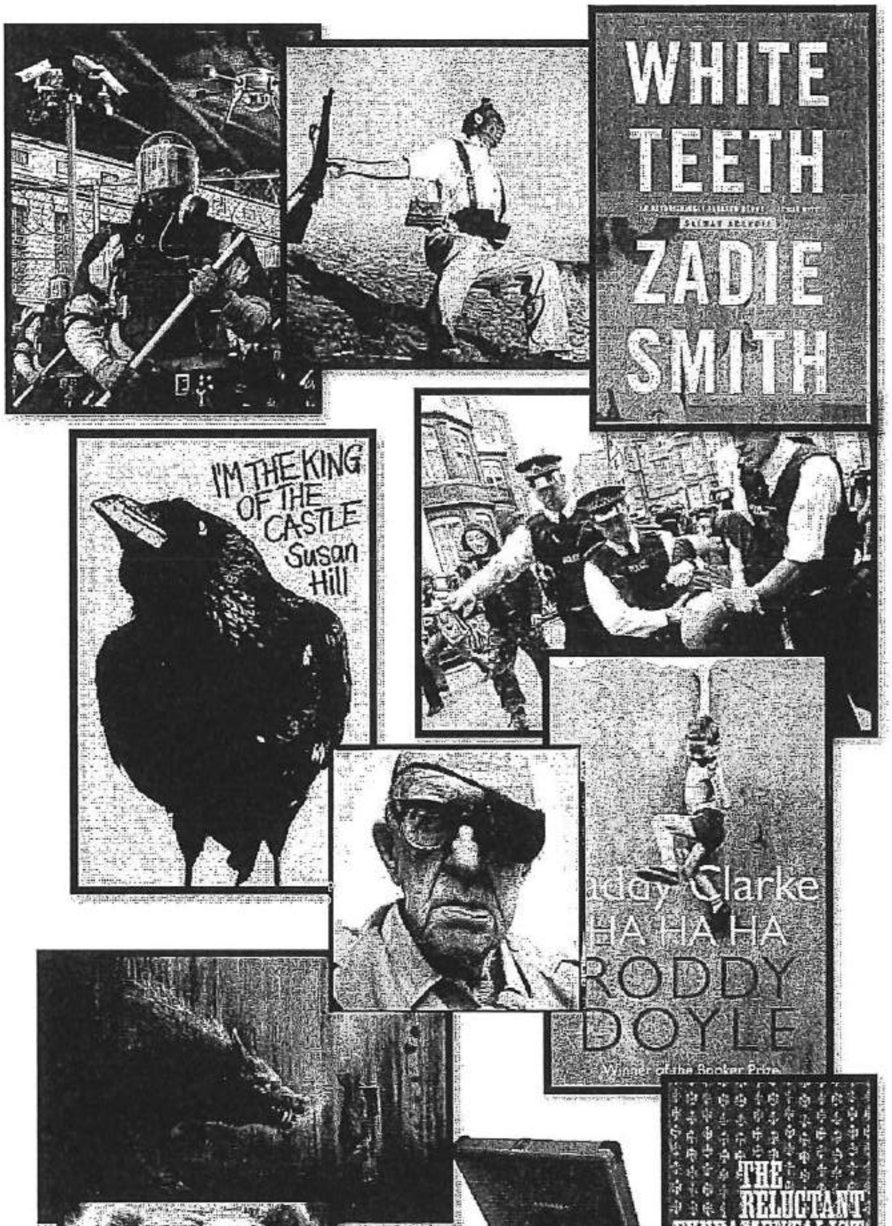
English

KS4

English

KS4

English Language
Paper 1: Fiction



INSTRUCTIONS

Paper 1 is about fiction texts. You will be given a fiction extract to read. In the first half of the exam you will have to answer questions about this extract. In the second half of the exam you will produce your own piece of creative writing. The exam is out of 80.

English Language Paper 1: Explorations in creative reading and writing (1 hour 45 minutes)

Q1: List four things about a specific part of the text (4 marks)

Q2: Analyse the writer's use of language (8 marks)

Q3: Analyse the structure of the whole text (8 marks)

Q4: You will be given a statement about the text. You need to write an essay arguing to what extent you agree with this statement (20 marks)

Q5: A choice of two writing tasks - **answer one** (40 marks)

Over the next 5 lessons, work through this booklet. At the front of the booklet there are a series of texts to read. Each one is followed by questions that will encourage you to use similar skills to those needed for the exam. There are also practice writing tasks at the back. Use this booklet and the notes in your exercise books to revise.

TEXT 1

Bring up the Bodies by Hilary Mantel

Falcons

Wiltshire, September 1535 His children are falling from the sky. He watches from horseback, acres of England stretching behind him; they drop, gilt-winged, each with a blood-filled gaze. Grace Cromwell hovers in thin air. She is silent when she takes her prey, silent as she glides to his fist. But the sounds she makes then, the rustle of feathers and the creak, the sigh and riffle of pinion, the small cluck-cluck from her throat, these are sounds of recognition, intimate, daughterly, almost disapproving. Her breast is gore-streaked and flesh clings to her claws.

Later, Henry will say, 'Your girls flew well today.' The hawk Anne Cromwell bounces on the glove of Rafe Sadler, who rides by the king in easy conversation. They are tired; the sun is declining, and they ride back to Wolf Hall with the reins slack on the necks of their mounts. Tomorrow his wife and two sisters will go out. These dead women, their bones long sunk in London clay, are now transmigrated. Weightless, they glide on the upper currents of the air. They pity no one. They answer to no one. Their lives are simple. When they look down they see nothing but their prey, and the borrowed plumes of the hunters: they see a flittering, flinching universe, a universe filled with their dinner.

All summer has been like this, a riot of dismemberment, fur and feather flying; the beating off and the whipping in of hounds, the coddling of tired horses, the nursing, by the gentlemen, of contusions, sprains and blisters. And for a few days at least, the sun has shone on Henry. Sometime before noon, clouds scudded in from the west and rain fell in big scented drops; but the sun re-emerged with a scorching heat, and now the sky is so clear you can see into Heaven and spy on what the saints are doing.

As they dismount, handing their horses to the grooms and waiting on the king, his mind is already moving to paperwork: to dispatches from Whitehall, galloped down by the post routes that are laid wherever the court shifts. At supper with the Seymours, he will defer any stories his hosts wish to tell: to anything the king may venture, tousled and happy and amiable as he seems tonight. When the king has gone to bed, his working night will begin.

Though the day is over, Henry seems disinclined to go indoors. He stands looking about him, inhaling horse sweat, a broad, brick-red streak of sunburn across his forehead. Early in the day he lost his hat, so by custom all the hunting party were obliged to take off theirs. The king refused all offers of substitutes. As dusk steals over the woods and fields, servants will be out looking for the stir of the black plume against darkening grass, or the glint of his hunter's badge, a gold St Hubert with sapphire eyes.

Already you can feel the autumn. You know there will not be many more days like these; so let us stand, the horseboys of Wolf Hall swarming around us, Wiltshire and the western counties stretching into a haze of blue; let us stand, the king's hand on his shoulder, Henry's face earnest as he talks his way back through the landscape of the day, the green copses and rushing streams, the alders by the water's edge, the early haze that lifted by nine; the brief shower, the small wind that died and settled; the stillness, the afternoon heat.

'Sir, how are you not burned?' Rafe Sadler demands. A redhead like the king, he has turned a mottled, freckled pink, and even his eyes look sore. He, Thomas Cromwell, shrugs; he hangs an arm

around Rafe's shoulders as they drift indoors. He went through the whole of Italy – the battlefield as well as the shaded arena of the counting house – without losing his London pallor. His ruffian childhood, the days on the river, the days in the fields: they left him as white as God made him. 'Cromwell has the skin of a lily,' the king pronounces. 'The only particular in which he resembles that or any other blossom.' Teasing him, they amble towards supper.

QUESTIONS (write in full sentences, use quotations)

Understanding

1. Explain what is happening in this extract.
2. When do you think the novel is set?
3. How would you describe the atmosphere in the text?
4. How is Thomas Cromwell presented?

Language / Structural Analysis

5. What is the effect of the opening sentence?
6. How does the writer's use of language appeal to the reader's senses?
7. How does the writer combine ideas of beauty, violence, tranquillity and death throughout the text?

TEXT 2

Spies by Michael Frayn

In this extract from chapter 2 of the novel, the narrator recalls a turning point in his childhood in England during the Second World War, when his friend Keith tells him something that sets off a complex chain of events.

Where the story began, though. was where most of our projects and adventures began – at Keith's house. At the tea table, in fact – I can hear the soft clinking made by the four blue beads that weighted the lace cloth covering the tall jug of lemon barley...

No, wait. I've got that wrong. The glass beads are clinking against the glass of the jug because the cover's stirring in the breeze. We're outside, in the middle of the morning, near the chicken run at the bottom of the garden, building the transcontinental railway.

Yes, because I can hear something else, as well - the trains on the real railway, as they emerge from the cutting on to the embankment above our heads just beyond the wire fence. I can see the showers of sparks they throw up from the live rail. The jug of lemon barley isn't our tea- it's our elevenses, waiting with two biscuits each on a tray his mother has brought us out from the house, and set down on the red brick path beside us. It's as she walks away, up the red brick path, that Keith so calmly and quietly drops his bombshell.

When is this? The sun's shining as the beads clink against the jug, but I have a feeling that there's still a trace of fallen apple blossom on the earthworks for the transcontinental railway, and that his

mother's worried about whether we're warm enough out there. 'You'll come inside, chaps, won't you, if you get chilly?' May still, perhaps. Why aren't we at school? Perhaps it's a Saturday or a Sunday. No, there's the feel of a weekday morning in the air; it's unmistakable, even if the season isn't. Something that doesn't quite fit here, as so often when one tries to assemble different bits to make a whole.

Or have I got everything back to front? Had the policeman already happened before this?

It's so difficult to remember what order things occurred in – but if you can't remember that, then it's impossible to work out which led to which, and what the connection was. What I remember, when I examine my memory carefully, isn't a narrative at all. It's a collection of vivid particulars. Certain words spoken, certain objects glimpsed. Certain gestures and expressions. Certain moods, certain weathers, certain times of day and states of light. Certain individual moments, which seem to mean so much, but which mean in fact so little until the hidden links between them have been found.

Where did the policeman come in the story? We watch him as he pedals slowly up the Close. His appearance has simultaneously justified all our suspicions and overtaken all our efforts, because he's coming to arrest Keith's mother... No, no- that was earlier. We're running happily and innocently up the street beside him, and he represents nothing but the hope of a little excitement out of nowhere. He cycles right past all the houses, looking at each of them in turn, goes round the turning circle at the end, cycles back down the street ... and dismounts in front of No. 12. What I remember for sure is the look on Keith's mother's face, as we run in to tell her that there's a policeman going to Auntie Dee's. For a moment all her composure's gone. She looks ill and frightened. She's throwing the front door open and not walking but running down the street...

I understand now, of course, that she and Auntie Dee and Mrs Berrill and the McAfees all lived in dread of policemen and telegraph boys, as everyone did then who had someone in the family away fighting. I've forgotten now what it had turned out to be- nothing to do with Uncle Peter, anyway. A complaint about Auntie Dee's blackout, I think. She was always rather slapdash about it.

Once again I see that look cross Keith's mother's face, and this time I think I see something else beside the fear. Something that reminds me of the look on Keith's face, when his father's discovered some dereliction in his duties towards his bicycle or his cricket gear: a suggestion of guilt. Or is memory being overwritten by hindsight once more?

If the policeman and the look had already happened, could they by any chance have planted the first seed of an idea in Keith's mind?

I think now that most probably Keith's words came out of nowhere, that they were spontaneously created in the moment they were uttered. That they were a blind leap of pure fantasy. Or of pure intuition. Or, like so many things, of both.

From those six random words, anyway, came everything that followed, brought forth simply by Keith's uttering them and by my hearing them. The rest of our lives was determined in that one brief moment as the beads clinked against the jug and Keith's mother walked away from us, through the brightness of the morning, over the last of the fallen white blossom on the red brick path, erect, composed, and invulnerable, and Keith watched her go, with the dreamy look in his eye that I remembered from the start of so many of our projects.

'My mother', he said reflectively, almost regretfully, 'is a German spy.'

QUESTIONS (write in full sentences, use quotations)

Understanding

1. Do you think the narrator trusts his memory? Why / why not?
2. Why did women at that time live "in dread of policemen and telegraph boys"?
3. What was the momentous thing that Keith told the narrator? Why would it have been so significant at the time?
4. Reading his account, do you believe that Keith's mother was a German spy? Explain your reasoning.

Language / Structural Analysis

5. How has the writer structured the passage in order to reflect the difficulty of recalling memories?
6. What impression of memory is created through the writer's choice of language?
7. The narrator describes his memory as "a collection of vivid particulars". Which precise sights, sounds and feelings have stayed in his memory from that time? Why do you think this is?

TEXT 3

The White Tiger by Aravind Adiga

A successful Indian entrepreneur called Balram has heard that the Prime Minister of China is about to visit India. Balram decides to write to the Prime Minister, giving an account of his rise from poverty. In this extract he recalls a surprise visit by a school inspector during his schooldays in a poor part of India known as the Darkness.

The inspector wrote four sentences on the board and pointed his cane at a boy:

'Read.'

One boy after the other stood up and blinked at the wall.

Try Balram, sir,' the teacher said. 'He's the smartest of the lot. He reads well.'

So I stood up, and read, 'We live in a glorious land. The Lord Buddha received his enlightenment in this land. The River Ganga gives life to our plants and our animals and our people. We are grateful to God that we were born in this land.'

Good,' the inspector said. 'And who was the Lord Buddha?'

'An enlightened man.'

'An enlightened god.'

(Oops! Thirty-six million and five—!)

The inspector made me write my name on the blackboard; then he showed me his wristwatch and asked me to read the time. He took out his wallet, removed a small photo, and asked me, 'Who is this man, who is the most important man in all our lives?'

The photo was of a plump man with spiky white hair and chubby cheeks, wearing thick earrings of gold; the face glowed with intelligence and kindness.

'He's the Great Socialist.'

'Good. And what is the Great Socialist's message for little children?'

I had seen the answer on the wall outside the temple: a policeman had written it one day in red paint.

'Any boy in any village can grow up to become the prime minister of India. That is his message to little children all over this land.'

The inspector pointed his cane straight at me. 'You, young man, are an intelligent, honest, vivacious fellow in this crowd of thugs and idiots. In any jungle, what is the rarest of animals – the creature that comes along only once in a generation?'

I thought about it and said:

'The white tiger.'

'That's what you are, in this jungle.'

Before he left, the inspector said, 'I'll write to Patna asking them to send you a scholarship. You need to go to a real school – somewhere far away from here. You need a real uniform, and a real education.'

He had a parting gift for me – a book. I remember the title very well: Lessons for Young Boys from the Life of Mahatma Gandhi.

So that's how I became the White Tiger. There will be a fourth and a fifth name too, but that's late in the story.

Now, being praised by the school inspector in front of my teacher and fellow students, being called a 'White Tiger', being given a book, and being promised a scholarship: all this constituted good news, and the one infallible law of life in the Darkness is that good news becomes bad news – and soon.

My cousin-sister Reena got hitched off to a boy in the next village. Because we were the girl's family, we were screwed. We had to give the boy a new bicycle, and cash, and a silver bracelet, and arrange for a big wedding – which we did. Mr Premier, you probably know how we Indians enjoy our weddings – I gather that these days people come from other countries to get married Indian-style. Oh, we could have taught those foreigners a thing or two, I tell you! Film songs blasting out from a black tape recorder, and drinking and dancing all night! I got smashed, and so did Kishan, and so did everyone in the family, and for all I know, they probably poured hooch into the water buffalo's trough.

Two or three days passed. I was in my classroom, sitting at the back, with the black slate and chalk that my father had brought me from one of his trips to Dhanbad, working on the alphabet on my own. The boys were chatting or fighting. The teacher had passed out.

Kishan was standing in the doorway of the classroom. He gestured with his fingers.

'What is it, Kishan? Are we going somewhere?'

Still he said nothing.

'Should I bring my book along? And my chalk?'

'Why not?' he said. And then, with his hand on my head, he led me out.

The family had taken a big loan from the Stork so they could have a lavish wedding and a lavish dowry for my cousin-sister. Now the Stork had called in his loan. He wanted all the members of the family working for him and he had seen me in school, or his collector had. So they had to hand me over too.

I was taken to the tea shop. Kishan folded his hands and bowed to the shopkeeper. I bowed to the shopkeeper too.

'Who's this?' The shopkeeper squinted at me.

He was sitting under a huge portrait of Mahatma Gandhi, and I knew already that I was going to be in big trouble.

My brother,' Kishan said. 'He's come to join me.'

Then Kishan dragged the oven out from the tea shop and told me to sit down. I sat down next to him. He brought a gunnysack; inside was a huge pile of coals. He took out a coal, smashed it on a brick, and then poured the black chunks into the oven.

'Harder,' he said, when I hit the coal against the brick. 'Harder, harder.'

Finally I got it right – I broke the coal against the brick. He got up and said, 'Now break every last coal in this bag like that.'

A little later, two boys came around from school to watch me. Then two more boys came; then two more. I heard giggling.

'What is the creature that comes along only once in a generation?' one boy asked loudly.

'The coal breaker,' another replied.

And then all of them began to laugh.

'Ignore them,' Kishan said. 'They'll go away on their own.'

He looked at me.

'You're angry with me for taking you out of school, aren't you?'

I said nothing.

'You hate the idea of having to break coals, don't you?'

I said nothing.

He took the largest piece of coal in his hand and squeezed it.

'Imagine that each coal is my skull: they will get much easier to break.'

He'd been taken out of school too. That happened after my cousin-sister Meera's wedding. That had been a big affair too.

QUESTIONS (write in full sentences, use quotations)

Understanding

1. How does Balram distinguish himself during the inspector's visit?
2. Why does the inspector consider 'White Tiger' to be an appropriate name for Balram?
3. What is the bad news for Balram that follows all the good news?

Language / Structural Analysis

4. What do we learn in this passage about the conditions in Balram's school and what is your impression of the way in which the inspection is conducted?
5. Explain the ways in which Balram's life is shown to be harsh.
6. How would you describe the narrative voice used in the passage?
7. Explain how the author has used contrast in the passage.

TEXT 4

The Thirty-Nine Steps by John Buchan

In this extract the narrator, Richard Hannay, is on the run from a gang of spies after escaping from a locked room in their farmhouse by using some explosive devices that he found there. Unable to travel away from the farm in daylight, he has now found a hiding place on top of a dovecote which he needs to climb in spite of having been injured in the explosion.

That was one of the hardest jobs I ever took on. My shoulder and arm ached like hell, and I was so sick and giddy that I was always on the verge of falling. But I managed it somehow. By the use of out-jutting stones and gaps in the masonry and a tough ivy root I got to the top in the end. There was a little parapet behind which I found space to lie down. Then I proceeded to go off into an old-fashioned swoon.

I woke with a burning head and the sun glaring in my face. For a long time I lay motionless, for those horrible fumes seemed to have loosened my joints and dulled my brain. Sounds came to me from the house – men speaking throatily and the throbbing of a stationary car. There was a little gap in the parapet to which I wriggled, and from which I had some sort of prospect of the yard. I saw figures come out – a servant with his head bound up, and then a younger man in knickerbockers. They were looking for something, and moved towards the mill. Then one of them caught sight of the wisp of cloth on the nail, and cried out to the other. They both went back to the house, and brought two more to look at it. I saw the rotund figure of my late captor, and I thought I made out the man with the lisp. I noticed that all had pistols.

For half an hour they ransacked the mill. I could hear them kicking over the barrels and pulling up the rotten planking. Then they came outside, and stood just below the dovecot, arguing fiercely. The servant with the bandage was being soundly rated. I heard them fiddling with the door of the

dovecot, and for one horrid moment I fancied they were coming up. Then they thought better of it, and went back to the house.

All that long blistering afternoon I lay baking on the roof-top. Thirst was my chief torment. My tongue was like a stick, and to make it worse I could hear the cool drip of water from the mill- lade. I watched the course of the little stream as it came in from the moor, and my fancy followed it to the top of the glen, where it must issue from an icy fountain fringed with cool ferns and mosses. I would have given a thousand pounds to plunge my face into that.

I had a fine prospect of the whole ring of moorland. I saw the car speed away with two occupants, and a man on a hill pony riding east. I judged they were looking for me, and I wished them joy of their quest.

But I saw something else more interesting. The house stood almost on the summit of a swell of moorland which crowned a sort of plateau, and there was no higher point nearer than the big hills six miles off. The actual summit, as I have mentioned, was a biggish clump of trees – firs mostly, with a few ashes and beeches. On the dovecot I was almost on a level with the tree- tops, and could see what lay beyond. The wood was not solid, but only a ring, and inside was an oval of green turf, for all the world like a big cricket-field.

I didn't take long to guess what it was. It was an aerodrome, and a secret one. The place had been most cunningly chosen. For suppose anyone were watching an aeroplane descending here, he would think it had gone over the hill beyond the trees. As the place was on the top of a rise in the midst of a big amphitheatre, any observer from any direction would conclude it had passed out of view behind the hill. Only a man very close at hand would realise that the aeroplane had not gone over but descended in the midst of the wood. An observer with a telescope on one of the higher hills might have discovered the truth, but only herds went there, and herds do not carry spy-glasses. When I looked from the dovecot I could see far away a blue line which I knew was the sea, and I grew furious to think that our enemies had this secret conning-tower to rake our waterways.

Then I reflected that if that aeroplane came back the chances were ten to one that I would be discovered. So through the afternoon I lay and prayed for the coming of darkness, and glad I was when the sun went down over the big western hills and the twilight haze crept over the moor. The aeroplane was late. The gloaming was far advanced when I heard the beat of wings and saw it vol-planning downward to its home in the wood. Lights twinkled for a bit and there was much coming and going from the house. Then the dark fell, and silence.

Thank God it was a black night. The moon was well on its last quarter and would not rise till late. My thirst was too great to allow me to tarry, so about nine o'clock, so far as I could judge, I started to descend. It wasn't easy, and half- way down I heard the back-door of the house open, and saw the gleam of a lantern against the mill wall. For some agonising minutes I hung by the ivy and prayed that whoever it was would not come round by the dovecot. Then the light disappeared, and I dropped as softly as I could on to the hard soil of the yard.

I crawled on my belly in the lee of a stone dyke till I reached the fringe of trees which surrounded the house. If I had known how to do it I would have tried to put that aeroplane out of action, but I realised that any attempt would probably be futile. I was pretty certain that there would be some kind of defence round the house, so I went through the wood on hands and knees, feeling carefully every inch before me. It was as well, for presently I came on a wire about two feet from the ground. If I had tripped over that, it would doubtless have rung some bell in the house and I would have been captured.

A hundred yards farther on I found another wire cunningly placed on the edge of a small stream. Beyond that lay the moor, and in five minutes I was deep in bracken and heather. Soon I was round the shoulder of the rise, in the little glen from which the mill-lade flowed. Ten minutes later my face was in the spring, and I was soaking down pints of the blessed water.

But I did not stop till I had put half a dozen miles between me and that accursed dwelling.

QUESTIONS (write in full sentences, use quotations)

Understanding

1. What conditions make the narrator's experience more uncomfortable?
2. What discovery does he make from the vantage point of the dovecote roof?
3. How does this discovery put him in more danger?

Language / Structural Analysis

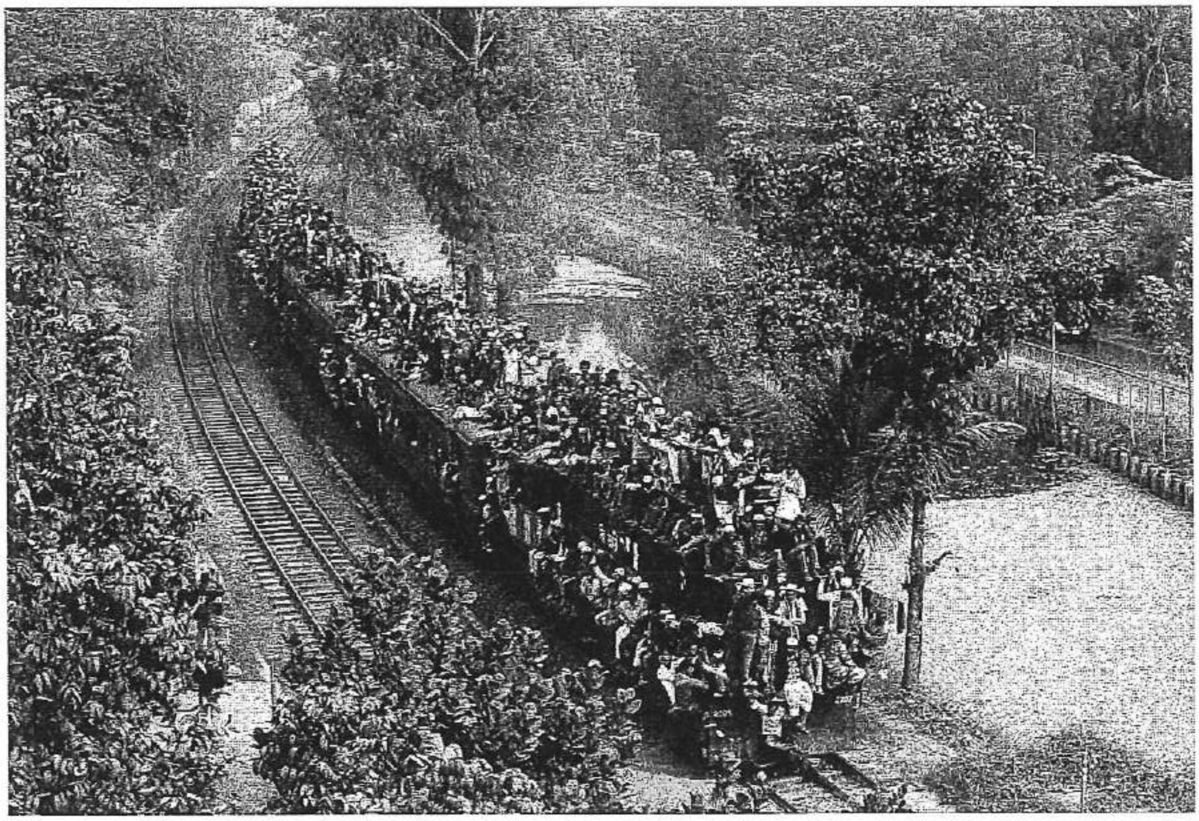
4. Identify three narrow escapes that the narrator has before the end of this passage. How does the account suggest that he is smarter than his enemies?
5. How does the description of the water appeal to our senses?
6. How does the final sentence of this passage close the episode and end the chapter satisfactorily for the reader?

WRITING TASKS

Q. You are going to enter a creative writing competition.

Your entry will be judged by a panel of people of your own age.

Either: Write a description suggested by this picture:



Or:

Write the opening part of a story about an exciting journey.

(24 marks for content and organisation 16 marks for technical accuracy) [40 marks]

Q. Your school or college is asking students to contribute some creative writing for its website.

Either: Write a description suggested by this picture:

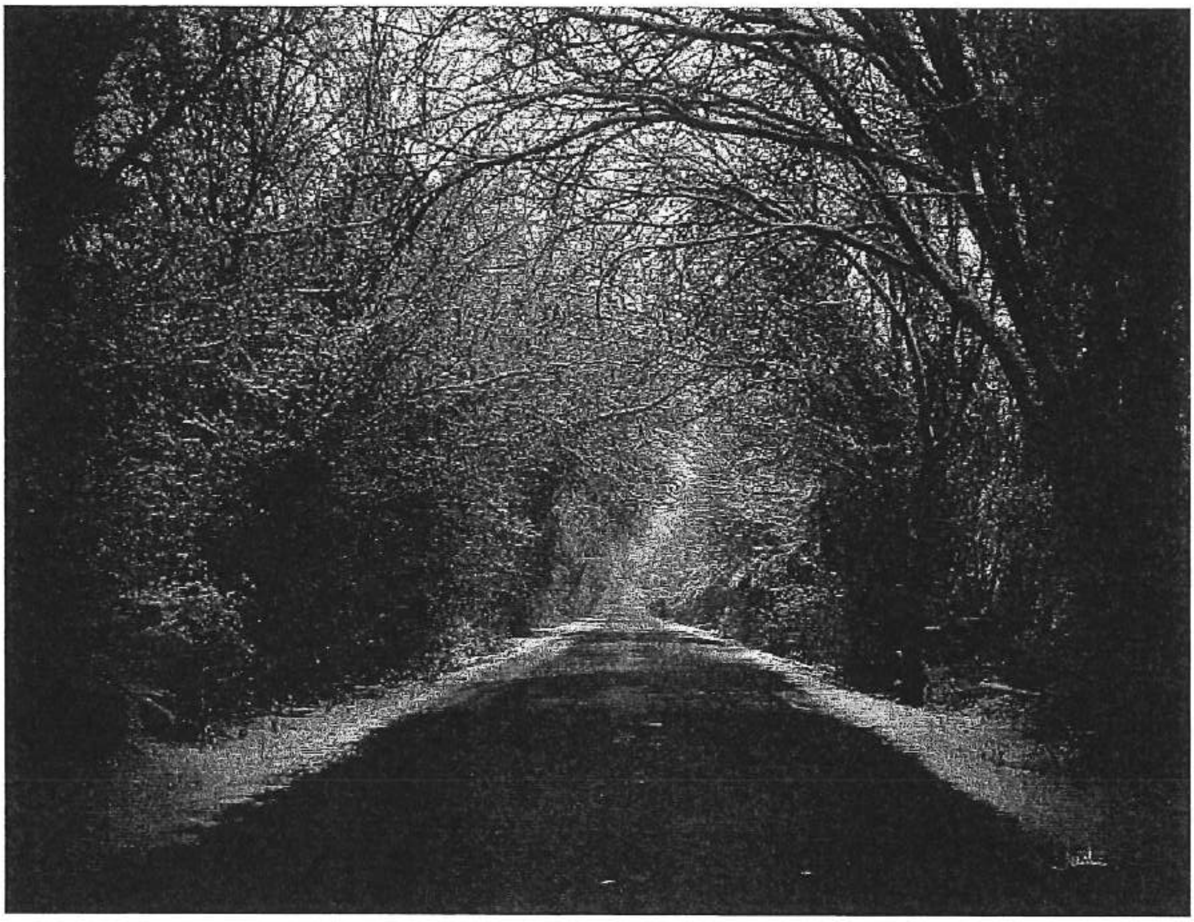
Or:

Describe an occasion when you went through a challenging experience.

(24 marks for content and organisation 16 marks for technical accuracy) [40 marks]

Q. You have been invited to produce a piece of creative writing about how children play imaginatively.

Either: Write a story set on a dark night as suggested by this picture:



Or:

Write a story about a dangerous location.

(24 marks for content and organisation 16 marks for technical accuracy) [40 marks]

KS4 Higher
Exclusion Pack

KS4 Higher Exclusion Pack

Ratio: Key facts

Example

A drink is made up of orange & grapefruit in the ratio 2 : 3. If there is 500ml of drink in a cup, how much is orange and how much is grapefruit.

Step 1 Add up the ratio numbers $2 + 3 = \mathbf{5}$

Step 2 Divide the total by this number $500 \div 5 =$ 100ml

Step 3 Multiply this by the proportion we are interested in
So orange = 2 x 100 = 200ml
grapefruit = 3 x 100 = 300ml

Questions to try

1). Divide £90 in the ratio 3 : 7.

2). A school collected £180 for charity. It was decided to divide the money between Dr. Barnados and the RSPCA in the ratio 2 : 3. How much did each charity receive ?

3). Pocket money is split between Pete, Alan and Helen in the ratio 4 : 5 : 6. Dad pays out £60, how much does each person get ?

4). £60 is split between Arnie, Barney and Clancey in the ratio 3 : 4: 5. How much does each one receive ?

5). Mr. Allen, Mr. Book and Mr. Collins own 4, 5, and 6 parts of a business respectively. The business makes £120 profit in a week. How much does each man get ?

Adding and subtracting fractions : Key facts

Try adding up these fractions

$$\frac{1^{\times 3}}{2_{\times 3}} + \frac{1^{\times 2}}{3_{\times 2}} = \frac{3}{6} + \frac{2}{6} = \frac{5}{6}$$

Step 1

Multiply by the bottom number in the other fraction

Step 2

Remember to multiply the top and the bottom by the same number

Questions to try

$\frac{1}{4} + \frac{1}{3} =$

$\frac{1}{7} + \frac{1}{2} =$

$\frac{2}{3} + \frac{1}{5} =$

$\frac{5}{7} - \frac{1}{4} =$

$\frac{5}{6} + \frac{3}{4} =$

Pie Charts: Key facts

Drawing Pie Charts

Remember:

$$\frac{360^*}{\text{Total Frequency}} = \text{Total angle per person}$$

Now- Multiply your answer by all the categories

24 people were asked for their favourite football team.
The results are in the table.

Football Team	Frequency	Degrees
Liverpool	3	3×15= 45°
Leeds United	7	
Manchester Utd	4	
Arsenal	2	
Manchester City	8	
	24	

Click next to see the table fill up with degrees.
Try to work them out before you click.

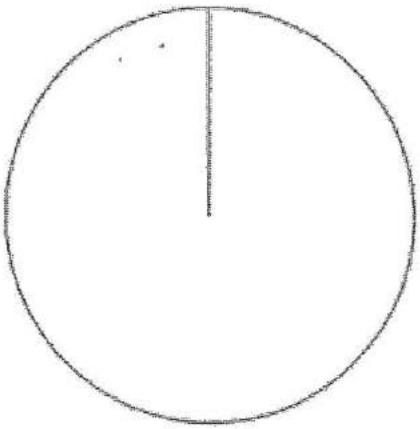
$$\frac{360}{24} = 15$$

Question to try:

Q1 The members of Four Ways Youth Club each choose an activity for an outing.
Their choices are shown in the table below.

Activity	Frequency
Bowling	8
Theme Park	14
Cinema	12
Other	6
	40

Construct a pie chart for this information.



Drawing graphs: Key facts

Two Operations:

Create a table

$y=3x+2$

x	-1	0	1	2	3	4
x3						
+2						
y						

Co-Ordinates

Questions to try (Just Draw the tables)

Easy	Medium	Hard
$y=2x+2$	$y=5x-2$	$y=2-2x$
$y=3x+1$	$y=3x-3$	$y=3-3x$
$y=7x+3$	$y=9x-7$	$y=x^2$

Percentage Increase and Decrease: Key facts

To find 10% divide by 10

To find 1% divide by 100

Remember to add on or subtract at the end of the question.

Depreciate means subtract in this context.

A pair of jeans is in a sale.

The sale offers 20% off all prices.

The jeans originally cost £38.

What was the price of the jeans in the sale?

find 20% → 38 ÷ 10 = 3·8 = 10%
7·6 = 20%

reducing so subtract

38 − 7.60 = £30·40

British Rail have decided to raise ticket prices by 17.5%.

Below is a list of prices before the increase. Work out the new ticket prices please.

To find 17.5% you need to find 10%. Then halve it to find 5%. Then halve it again to find 2.5%. Then add the three parts up.

Liverpool-London Return

£60

Liverpool-Edinburgh Return

£50

Liverpool-Paris Return

£90

Liverpool-Rome Return

£130

Stem and leaf: Key facts

Remember to put on a key!

The stem and Leaf diagram must be ordered

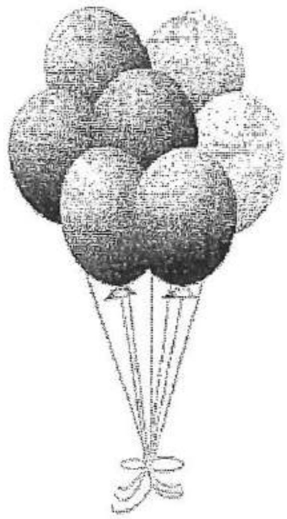
1	3 4 8 8 9
2	0 1 2 2 4 6 6 6 7 7 8 9
3	1 1 2 2
4	2 3 6
5	1 8 9
6	5 9
7	6

Key 6|5 =65

Questions to try

Complete a Stem and Leaf diagram for this party of 30 people.

47	29	41	28	38	51	43	42	65	46
42	32	58	72	59	57	46	41	63	44
61	52	39	71	42	47	53	62	72	55



Find the median, mode and modal group and range for this data.

Area and Circumference of a circle

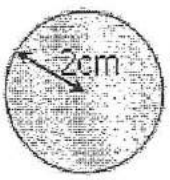
Key facts:

Area of a circle $A = \pi r^2$ **or** $A = \pi \times r \times r$

Circumference of a circle $C = \pi \times d$

The area of a circle

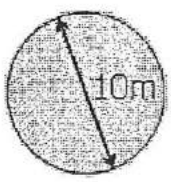
Use $\pi = 3.14$ to find the area of the following circles:



$A = \pi r^2$

$= 3.14 \times 2^2$

$= 12.56cm^2$



$A = \pi r^2$

$= 3.14 \times 5^2$

$= 78.5m^2$

$A = \pi r^2$

$= 3.14 \times 23^2$

$= 1661.06mm^2$

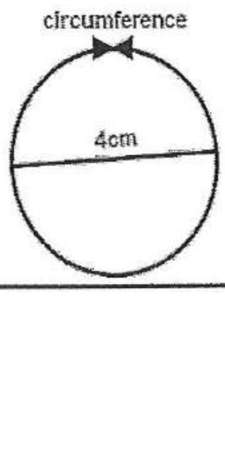
$A = \pi r^2$

$= 3.14 \times 39^2$

$= 4775.94cm^2$

Example 1

Find the circumference of this circle

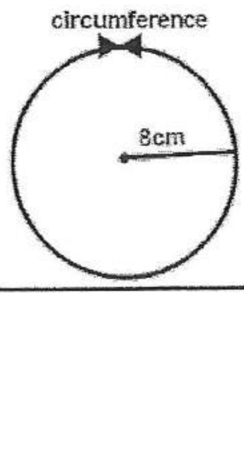


Circumference
$= \pi \times$ diameter

Circumference
$= \pi \times 4$
= <u>12·57cm (2 d.p.)</u>

Example 2

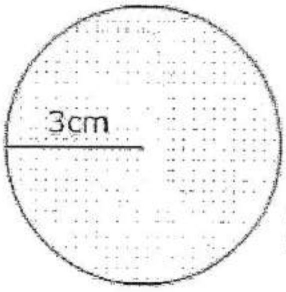
Find the circumference of this circle



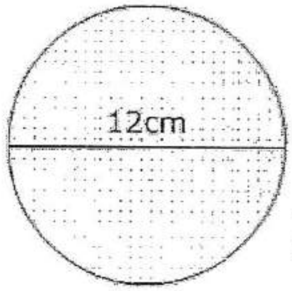
Circumference
$= \pi \times$ diameter

Circumference
$= \pi \times 16$
= <u>50·27cm (2 d.p.)</u>

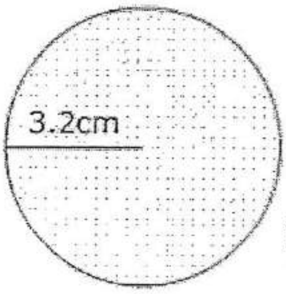
Calculate the area and the circumference of :



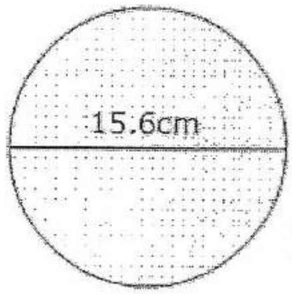
Area = cm² [2]



Area = cm² [2]



Area = cm² [2]

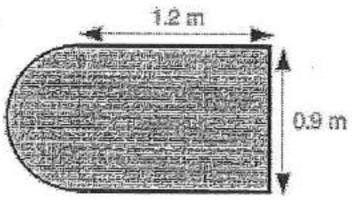


Area = cm² [2]

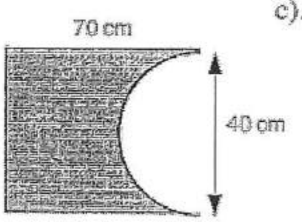
Extension: Tip to find a semicircle half a circle

14). Find the area and perimeter of the shaded regions in the following shapes.

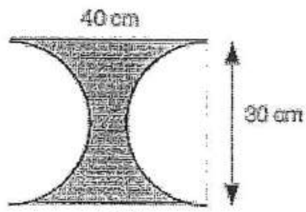
a).



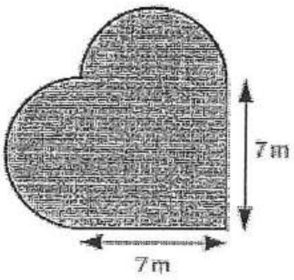
b).



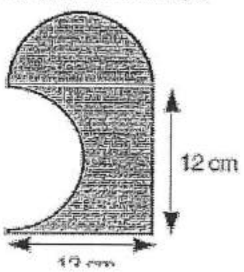
c).



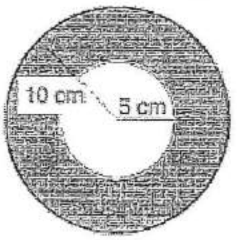
d).



e).

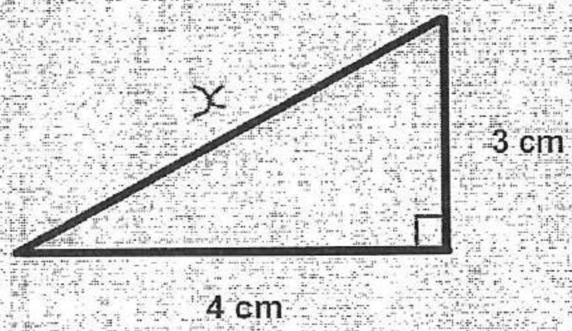


f).



Pythagoras : Key facts

E.g. 1



So:

$$3^2 + 4^2 = x^2$$

$$9 + 16 = x^2$$

$$25 = x^2$$

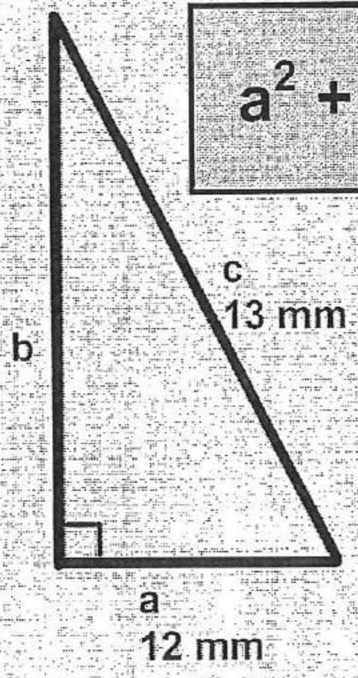
$$\sqrt{25} = x$$

$$5 = x$$

$$a^2 + b^2 = c^2$$

E.g. 2

$$a^2 + b^2 = c^2$$



$$13^2 = 12^2 + b^2$$

$$169 = 144 + b^2$$

$$-144 \quad -144$$

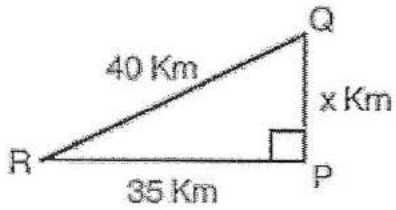
$$25 = b^2$$

$$\sqrt{25} = b$$

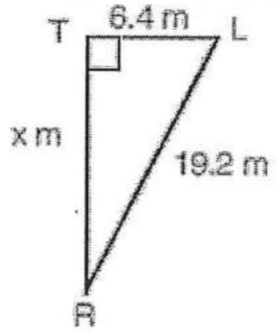
$$5 = b$$

Some to try:

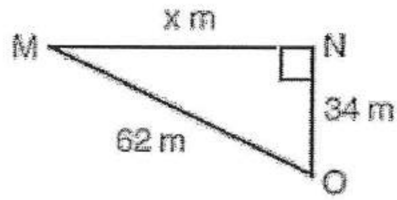
26).



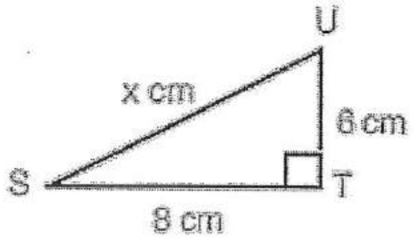
27).



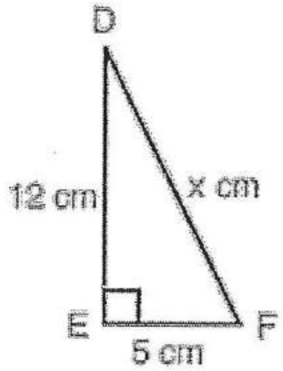
28).



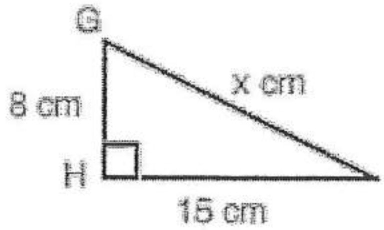
1).



2).



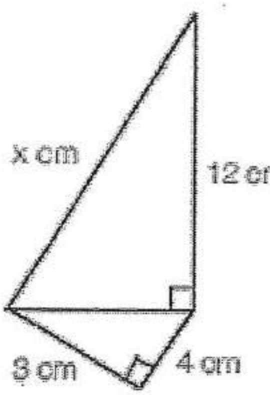
3).



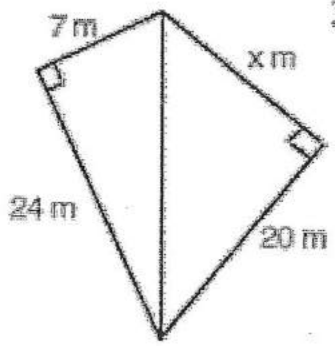
Extension:

D. Find the length of the side marked "x".

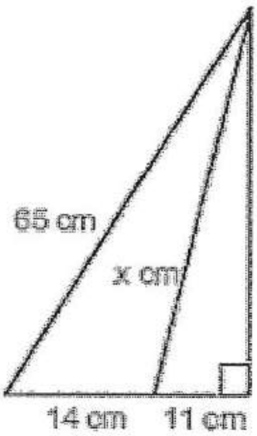
1).



2).



3).



Simultaneous Equations: Key facts

$$\times 3 \quad 4x - 2y = 7$$
$$\times 4 \quad 3x - 4y = 4$$

Multiply the other equation by the amount of x in the other equation

$\times 3 \quad 12x - 6y = 21$

$\times 4 \quad 12x - 16y = 16$

Now Subtract the equations if the signs are the same or add them if it is different

$-6 - -16 = 10y \rightarrow 10y = 5$

$21 - 16 = 5$

$y = \frac{5}{10}$ $\underline{y = 0.5}$

$4x - 2 \times 0.5 = 7$

$4x - 1 = 7$, $+1$

$4x = 8$

$x = \frac{8}{4}$ $\underline{x = 2}$

Now substitute back in to an original equation

Questions to try:

Solve the simultaneous equations

$$3x + 7y = 26$$
$$4x + 5y = 13$$

Solve the simultaneous equations.

$$5a + 3b = 9$$
$$2a - 3b = 12$$

Compound interest: Key facts

Compound Interest

Worked Example 1 | Long Method

£2000 is invested at 6% compound interest for 3 years.
Find: (a) the amount in the account at the end of the period.
and (b) the interest accrued.

Amount after 1 year = 2000 + 6% of 2000 = 2000 + 120 = £2120

Amount after 2 years = 2120 + 6% of 2120 = 2120 + 127.20 = £2247.20

Amount after 3 years = 2247.20 + 6% of 2247.20 = 2247.20 + 134.83 = £2382.03

Interest accrued = £2382.03 - £2000 = £382.03

Compound Interest

Worked Example 1 | Efficient Method

£2000 is invested at 6% compound interest for 3 years.
Find: (a) the amount in the account at the end of the period.

(a) Money at end of 3 years = 2000×1.06^3 = £2382.03 ✓

Explanation of the Method

Remember that 6% means $\frac{6}{100} = 0.06$

At the end of each year the money grows to 106% of its value at the start of the year = $\frac{106}{100} = 1.06$

After 1 year the money has been multiplied by 1.06 → 2000×1.06

After 2 years the money is again multiplied by 1.06 → $(2000 \times 1.06) \times 1.06$

After 3 years the money is again multiplied by 1.06 → $(2000 \times 1.06 \times 1.06) \times 1.06$

So after 3 years the money will have grown to £2000×1.06^3.

If the term had been 7 years and the interest rate 8% then we would simply have calculated 2000×1.08^7.

Remember that the amount is decreasing in will reduce every year. Per annum means every year. Depreciate means reducing.

Worked Example 1:

£2000 is invested at 6% compound interest for 3 years.

Find: (a) the amount in the account at the end of the period and (b) the interest accrued.

Q1. £600 is invested at 5% compound interest for 3 years.
Find: (a) the amount in the account at the end of the period. and (b) the interest accrued.

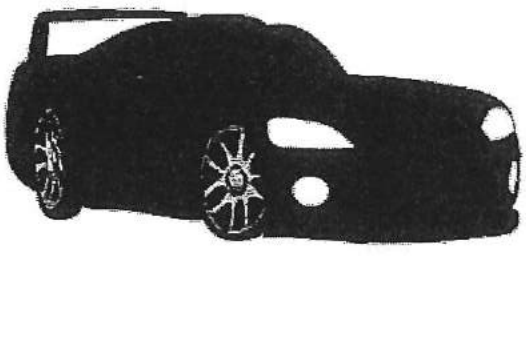
Q2. £5000 is invested at 8% compound interest for 4 years.
Find: (a) the amount in the account at the end of the period (nearest £) and (b) the interest accrued (nearest £)

Remember with the question below the decimal multiplier will be 100%-8%........

A car is bought for £17,000, a nice Toyota Celica.

The car loses 8% of its value every year due to old age and wear and tear (depreciation).

How much will the car be worth after 3 years?



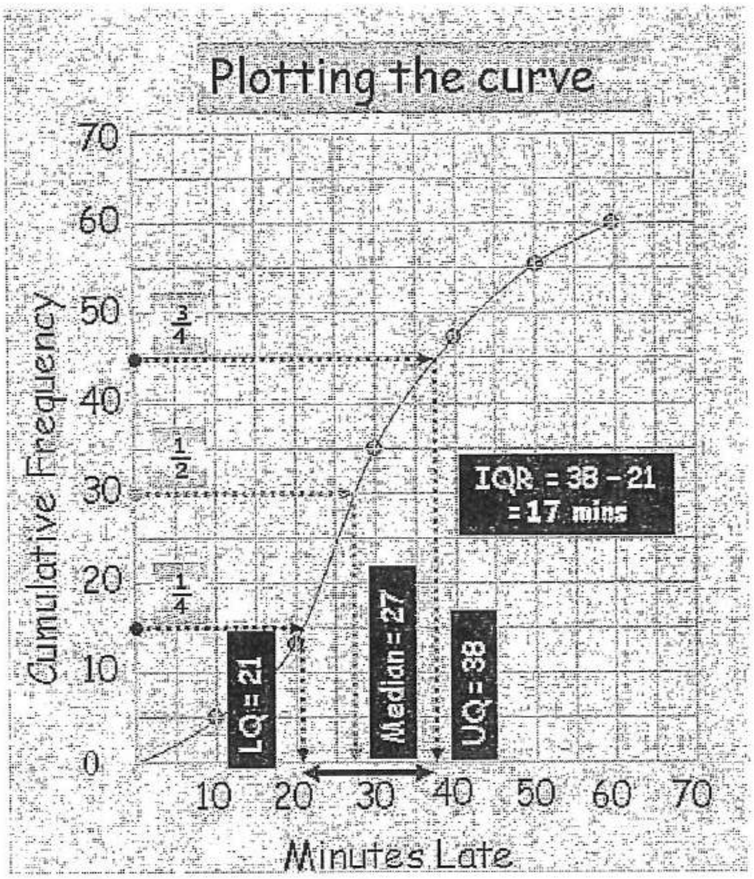
Cumulative Frequency: Key points

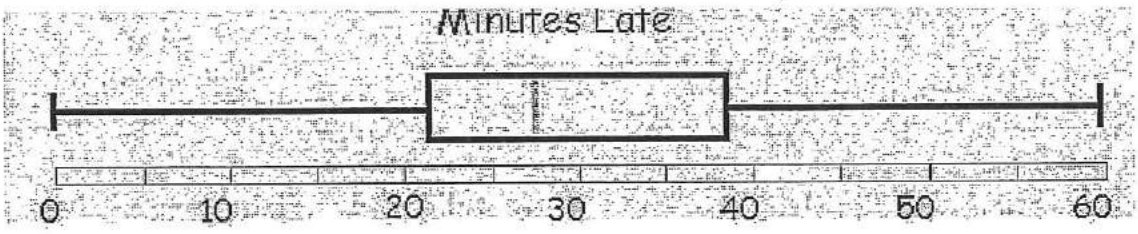
Cumulative frequency table

Minutes Late	Frequency	Upper Limit	Cumulative Frequency
0 - 10	5	< 10	5
10 - 20	8	< 20	13
20 - 30	22	< 30	35
30 - 40	12	< 40	47
40 - 50	8	< 50	55
50 - 60	5	< 60	60

Cumulative frequency just means running total.

Plot the upper limit!

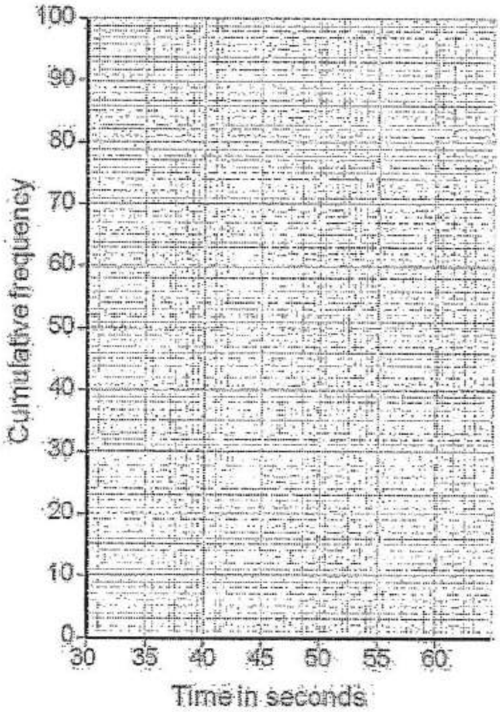




Lowest score **Lower Quartile** **median** **Upper quartile** **Highest score**

Question for you to try:

Time in seconds	Frequency	Cumulative frequency
$30 < t \leq 35$	9	
$35 < t \leq 40$	12	
$40 < t \leq 45$	24	
$45 < t \leq 50$	28	
$50 < t \leq 55$	16	
$55 < t \leq 60$	11	



Factorising and expanding: Key points

Factorising Expressions

- Take out a common factor and put the rest in a bracket

eg 1 $20y - 12 = \boxed{4}(\boxed{5y - 3})$

$$8x + xy = \boxed{x}(\boxed{8 + y})$$

Tip: remember to factorise fully:

KS4 Foundation Exclusion Pack

KS4 Foundation Exclusion Pack_

Number

1. Work out 362×54
You **must** show all your working.

....
(Total 3 marks)

2. (a) Work out

(i) $3 - 11$

....

(ii) -3×-5

....
(2)

(b) Work out $\frac{7}{8} - \frac{1}{4}$

....
(2)
(Total 4 marks)

3. Work out 35% of £400

£ ....
(Total 2 marks)

4. (a) Write 0.15 as a percentage.

.... %
(1)

(b) Write 35% as a fraction.
Give your answer in its simplest form.

....
(2)
(Total 3 marks)

5. Write these numbers in order of size.
Start with the smallest number.

(i) 75, 56, 37, 9, 59

....

(ii) 0.56, 0.067, 0.6, 0.65, 0.605

....

(iii) $5, -6, -10, 2, -4$

....

(iv) $\frac{1}{2}, \frac{2}{3}, \frac{2}{5}, \frac{3}{4}$

....

(Total 5 marks)

6. Write these numbers in order of size.
Start with the smallest number.

(a) –6, 2, –1, 0, –3

....

(1)

(b) 0.6, 0.64, 0.06, 0.604, 0.064

....

(1)
(Total 2 marks)

7. Write the number 3927 correct to 1 significant figure.

....

(Total 1 mark)

8. There are 800 people on a train at Manchester.

$\frac{1}{10}$ of these 800 people are children.

(i) Work out $\frac{1}{10}$ of 800

....

$\frac{3}{8}$ of these 800 people are women.

(ii) Work out $\frac{3}{8}$ of 800

....

(Total 3 marks)

9. (a) Work out $\frac{4}{5}$ of 30

....

(2)

(b) Write $\frac{4}{5}$ as a decimal.

....

(2)
(Total 4 marks)

10. (a) Write 0.85 as a percentage.

.... %

(1)

(b) Write $\frac{1}{10}$ as a percentage.

.... %

(1)

(c) Write 60% as a decimal.

....

(1)
(Total 3 marks)

11. Work out 70% of £340

£ ....

(Total 2 marks)

12. (a) Write 0.38 as a percentage.

.... %

(1)

(b) Write $\frac{3}{10}$ as a percentage.

.... %

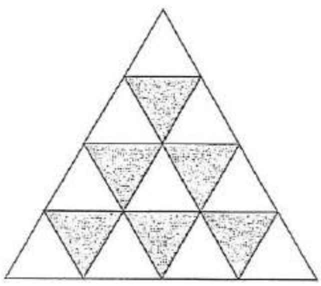
(1)
(Total 2 marks)

13. Richard paid 56p for 7 pencils.
The cost of each pencil was the same.
Work out the cost of 4 of these pencils.

.... p

(Total 2 marks)

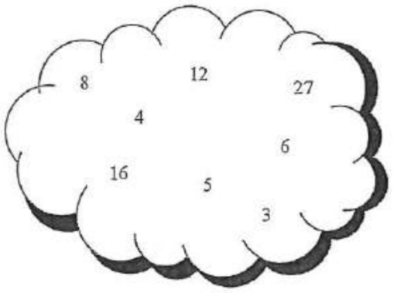
14.



What fraction of the large triangle is shaded?
Give your fraction in its simplest form.

....
(Total 2 marks)

15.



Using only the numbers in the cloud, write down

(i) all the multiples of 6, ...

(ii) all the square numbers, ...

(iii) all the factors of 12, ...

(iv) all the cube numbers. ....
(Total 4 marks)

16. (a) Write **three hundred and fifty thousand** in figures.

....
(1)

(b) (i) Write 25 400 in words.

....

(ii) Write down the value of the **5** in 25 400.

....
(2)

(c) (i) Write 25 730 correct to the nearest thousand.

....

(ii) Write 25 730 correct to the nearest hundred.

....
(2)
(Total 5 marks)

17. Simplify the ratio 12 : 16

....
(Total 1 mark)

18. Work out $\frac{2}{3} \times \frac{5}{6}$

Give your answer as a fraction in its simplest form.

....

(Total 2 marks)

19. (a) Write 0.060 172 correct to 1 significant figure.

....

(1)

(b) Write 28 473 correct to 1 significant figure.

....

(1)
(Total 2 marks)

20. (a) Write down the value of the 5 in the number 54 327.

....

(1)

(b) Write 0.874 correct to 1 significant figure.

....

(1)
(Total 2 marks)

21. Write these five numbers in order of size.
Start with the smallest number.

2.5 0.5 0.52 2.2 0.25

....

(Total 2 marks)

22. (a) Write down all the prime numbers between 40 and 50.

....

(2)

(b) Write down the cube of 10.

....

(1)
(Total 3 marks)

23. 2, 8, 12, 15, 21, 24, 36, 43

Write down a number from the list that is

(i) a square number,

....

(ii) a cube number.

....

(Total 2 marks)

24. Fatima bought 48 teddy bears at £9.55 each.

(a) Work out the total amount she paid.

£ ....

(3)

Fatima sold all the teddy bears for a total of £696.

She sold each teddy bear for the same price.

(b) Work out the price at which Fatima sold each teddy bear.

£ ....

(Total 6 marks)

25. 800 students are going on a school trip by bus. Each bus can carry 34 students.

Work out the smallest number of buses needed to carry all the students.

....

(Total 2 marks)

26. Here are some fractions.

$\frac{2}{8}$	$\frac{3}{10}$	$\frac{4}{16}$	$\frac{5}{20}$	$\frac{8}{24}$

Two of the fractions are **not** equivalent to $\frac{1}{4}$.

Tick the boxes underneath each of these **two** fractions.

(Total 2 marks)

27.

Waxworks Adult ticket: £8.50 Child ticket: £4.50

Mr and Mrs Jones take their three children to the Waxworks.
Mrs Jones pays for 2 adult tickets and 3 child tickets.
She pays with a £50 note.

How much change should she receive from £50?

£ ....

(Total 3 marks)

28. Here is a list of eight numbers.

5 6 12 20 25 26 28 33

(a) From the list, write down

(i) a square number,

....

(ii) a number that is a multiple of 7,

....

(iii) **two** numbers that are factors of 40,

.... and ....

(iv) **two** numbers with a sum of 59.

.... and ....

(4)

(b) Tony says that "6 is a cube number because $2^3 = 6$".
Tony is wrong. Explain why.

....

(1)
(Total 5 marks)

29. (a) Work out $500 - 107$

....

(2)

(b) Work out 327×4

....

(2)
(Total 4 marks)

30. (a) Write the number 5250 in words.

....

(1)

(b) Write 23 250 to the nearest thousand. ....

(1)

(c) Write down the value of the 3 in the number 42 350

....

(1)

(d) Write **six thousand three hundred and seventy four** in figures.

....

(1)
(Total 4 marks)

31. (a) Write $\frac{1}{10}$

(i) as a decimal,

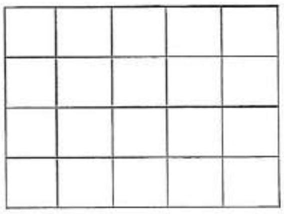
............................cm

(ii) as a percentage.

............................cm

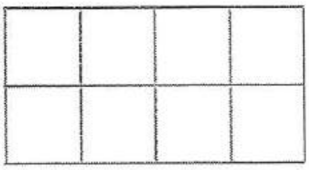
(2)

(b) Shade $\frac{3}{5}$ of this shape.



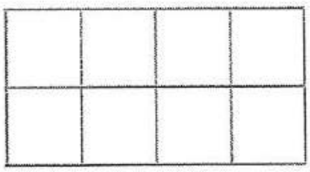
(1)
(Total 3 marks)

32. (a) Shade $\frac{3}{4}$ of this shape.



(1)

(b) Shade 0.25 of this shape.



(1)

(c) Change 0.3 into a fraction.

....

(1)

(d) Change 0.7 into a percentage.

.... %

(1)

(e) Work out $\frac{3}{4}$ of £36

£ ....

(2)
(Total 6 marks)

33. Work out

(i) $2 \times 3 + 4$

....

(ii) $10 - 2 \times 5$

....

(iii) $16 \div (2 \times 4)$

....

(Total 3 marks)

34. The table shows the temperature on the surface of each of five planets.

Planet	Temperature
Venus	480 °C
Mars	− 60 °C
Jupiter	− 150 °C
Saturn	− 180 °C
Uranus	− 210 °C

(a) Work out the difference in temperature between Mars and Jupiter.

......................°C

(1)

(b) Work out the difference in temperature between Venus and Mars.

......................°C

(1)

(c) Which planet has a temperature 30 °C higher than the temperature on Saturn?

....

(1)

The temperature on Pluto is 20 °C lower than the temperature on Uranus.

(d) Work out the temperature on Pluto.

......................°C

(1)
(Total 4 marks)

35. Work out $60 \times \dfrac{2}{3}$

....

(2)
(Total 2 marks)

36. Work out 286×43

....

(Total 3 marks)

37. (a) Write these five fractions in order of size.
Start with the smallest fraction.

$$\frac{3}{4} \quad \frac{1}{2} \quad \frac{3}{8} \quad \frac{2}{3} \quad \frac{1}{6}$$

....

(2)

(b) Write these numbers in order of size.
Start with the smallest number.

$$65\% \quad \frac{3}{4} \quad 0.72 \quad \frac{2}{3} \quad \frac{3}{5}$$

....

(2)
(Total 4 marks)

38. Simplify the ratio 6 : 9

....

Algebra

1. Simplify

(i) $c + c + c + c$

....

(ii) $p \times p \times p \times p$

....

(iii) $3g + 5g$

....

(iv) $2r \times 5p$

....

(4)
(Total 4 marks)

2. Here are the first five terms of a number sequence.

1 5 10 16 23

Write down the next **two** terms of the sequence.

....

(Total 2 marks)

3. (a) Solve $4x = 32$

$x =$ ....

(1)

(b) Solve $y - 3 = 11$

$y =$ ....

(1)
(Total 2 marks)

4. Here are the first five terms of a number sequence.

3 8 13 18 23

(a) Write down the next **two** terms of the sequence.

............, ...

(2)

(b) Explain how you found your answer.

....

(1)

(c) Explain why 387 is **not** a term of the sequence.

....

(1)
(Total 4 marks)

5. (a) Solve $6x = 18$

$x =$ ....

(1)

(b) Solve $2y + 3 = 8$

$y =$ ....

(2)
(Total 3 marks)

6. $v = u + 10t$

Work out the value of v when

$u = 10$ and $t = 7$

$v =$ ....

(Total 2 marks)

7. (a) Solve $2y = 8$

$y =$ ....

(1)

(b) Solve $t - 4 = 7$

$t =$ ....

(1)

(Total 2 marks)

8. (a) Simplify $y + y$

....

(1)

(b) Simplify $p^2 + p^2 + p^2$

....

(1)

(Total 2 marks)

9. $S = 2p + 3q$

$p = -4$
$q = 5$

(a) Work out the value of S.

$S =$ ....

(2)

$T = 2m + 30$

$T = 40$

(b) Work out the value of m.

$m =$ ....

(2)

(Total 4 marks)

10. Simplify

(a) $c + c + c$

....

(1)

(b) $e + f + e + f + e$

....

(1)

(c) $2a + 3a$

....

(1)

(d) $2xy + 3xy - xy$

....

(1)

(e) $3a + 5b - a + 2b + 8$

(2)

(Total 6 marks)

11. Solve $3x = 18$

$x =$...................

(Total 1 mark)

12. Here are the first 5 terms of a number pattern.

3 7 11 15 19

(a) Write down the next term in the number pattern.

(1)

(b) Work out the 8th term in the number pattern.

(1)

(Total 2 marks)

13. (a) Simplify

(i) $e + f + e + f + e$

....

(ii) $p^2 + p^2 + p^2$

....

(2)

(b) Work out the value of $5x + 1$ when $x = -3$

....

(2)

(Total 4 marks)

14. Imran thinks of a number.

He multiplies the number by 3.
He then adds 19.
His answer is 61.
What number did Imran first think of?

....
(Total 2 marks)

15. (a) Solve $x + 2x = 12$

$x =$ ....

(1)

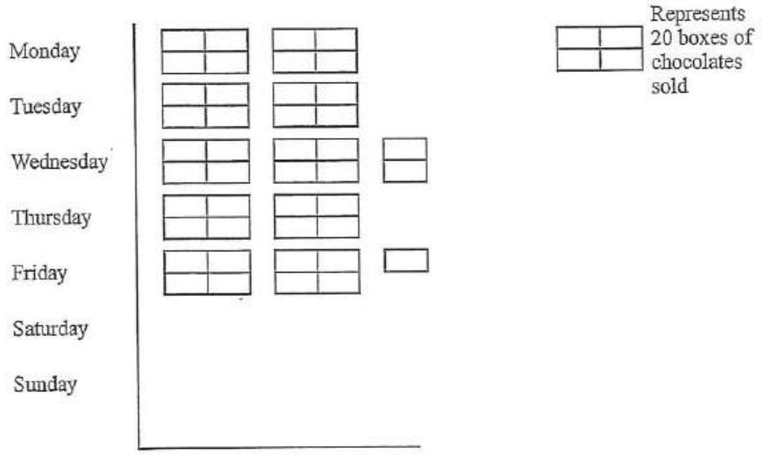
(b) Solve $2y - 1 = 13$

$y =$ ....

(2)
(Total 3 marks)

Data

1. Here is a pictogram.
It shows the number of boxes of chocolates sold last week from Monday to Friday.



(a) Write down the number of boxes of chocolates sold on

(i) Monday, ...

(ii) Wednesday. ....

(2)

On Saturday, 100 boxes of chocolates were sold.

(b) Show this on the pictogram.

(1)

On Sunday, 55 boxes of chocolates were sold.

(c) Show this on the pictogram.

(1)
(Total 4 marks)

2. Mary threw a dice 24 times.

Here are the 24 scores.

3	5	3	4	1	2	4	5
6	2	3	4	3	1	4	3
2	3	5	5	3	4	2	1

(a) Complete the frequency table.

Score	Tally	Frequency
1		
2		
3		
4		
5		
6		

(b) Write down the mode.

....

(1)
(Total 4 marks)

3. Here are the shoe sizes of 6 students.

2 10 7 6 10 9

Work out the median shoe size.

....
(Total 2 marks)

4. 60 British students each visited one foreign country last week.
The two-way table shows some information about these students.

	France	**Germany**	**Spain**	**Total**
Female			9	34
Male	15			
Total		25	18	60

(a) Complete the two-way table.

(3)

One of these students is picked at random.

(b) Write down the probability that the student visited Germany last week.

....
(1)
(Total 4 marks)

5. The stem and leaf diagram shows information about the pulse rate of each of 15 students.

Pulse rate

5	6 8
6	0 2 3 8
7	1 4 6 6 8
8	7 8 9
9	7

Key:
5 | 6 means 56

(a) Work out the range of the pulse rates.

....
(1)

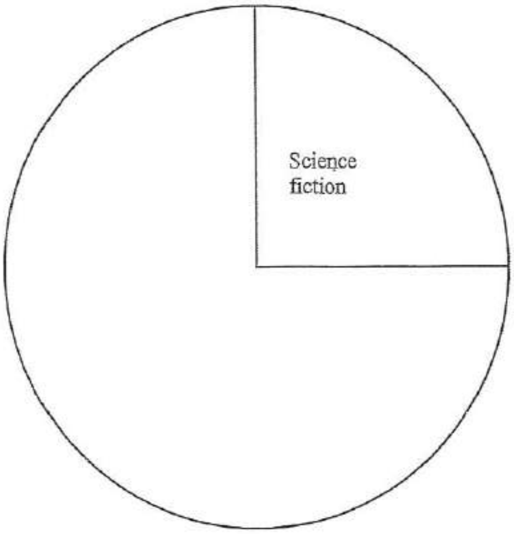
(b) Find the median pulse rate.

....
(1)
(Total 2 marks)

6. The table shows information about 60 DVDs.

Type of DVD	Number of DVDs	Angle
Science fiction	15	90°
Comedy	20	
Musical	12	
Thriller	13	

(a) Complete the pie chart.



(3)

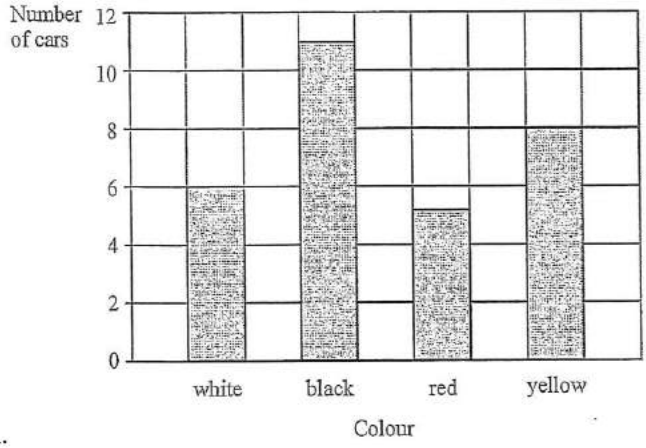
Paul takes a DVD at random.

(b) Write down the probability that he takes a Science fiction DVD.

....

(1)
(Total 4 marks)

7. Jerry recorded the colour of each of the cars he saw one morning.



The bar chart shows this information.

(a) Write down the number of red cars.

....

(1)

(b) Which was the most popular colour of car?

....

(1)
(Total 2 marks)

8. Sarah watched a water ride at a theme park.
She counted the number of people in each of 20 boats.
These numbers are shown below.

2 3 1 2 2 3 4 5 4 1

1 2 2 3 2 4 5 4 2 4

(a) Complete the frequency table.

Number of people in a boat	Tally	Frequency
1		
2		
3		
4		
5		

(2)

(b) Write down the mode of the number of people in a boat.

....

(1)

Emily asked 5 people the number of rides each of them had been on.
The numbers are shown below.

6 8 7 6 10

(c) Work out the mean number of rides per person.

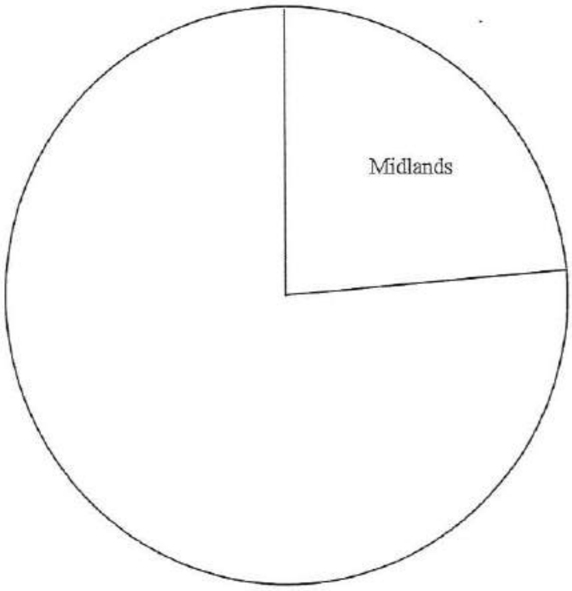
....

(3)
(Total 6 marks)

9. Bhavana asked some people which region their favourite football team came from.
The table shows her results.

Region	**Frequency**	
Midlands	22	
London	36	
Southern England	8	
Northern England	24	

Complete the accurate pie chart to show these results.
Use the circle given below.



(Total 3 marks)

10. Bob carried out a survey of 100 people who buy tea.

He asked them about the tea they buy most.

The two-way table gives some information about his results.

	Tea bags	Packet tea	Instant tea	Total
50 g	2	0	5	
100 g	35	20		60
200 g	15			
Total		25		100

Complete the two-way table.

(Total 3 marks)

11. Here are the test marks of 6 girls and 4 boys.

Girls:	5	3	10	2	7	3
Boys:	2	5	9	3		

(a) Write down the mode of the 10 marks.

....

(1)

(b) Work out the median mark of the **boys**.

....

(2)

(c) Work out the range of the **girls'** marks.

....

(1)

(d) Work out the mean mark of all 10 students.

....

(2)
(Total 6 marks)

12. Peter rolled a 6-sided dice ten times.
Here are his scores.

3 2 4 6 3 3 4 2 5 4

(a) Work out the median of his scores.

....

(2)

(b) Work out the mean of his scores.

....

(2)

(c) Work out the range of his scores.

....

(1)
(Total 5 marks)

13. Chloe made a list of her homework marks.

4 5 5 5 4 3 2 1 4 5

(a) Write down the mode of her homework marks.

....

(1)

(b) Work out her mean homework mark.

....

(2)
(Total 3 marks)

14. Mr Smith kept a record of the number of absences for each student in his class for one term.

Here are his results.

0 0 0 8 4 5 5 3 2 1

(a) Write down the mode.

....

(1)

(b) Work out the mean.

....

(2)
(Total 3 marks)

15. Mark throws a fair coin.
He gets a Head.

Mark's sister then throws the same coin.

(a) What is the probability that she will get a Head?

....

(1)

Mark throws the coin 30 times.

(b) Explain why he may not get exactly 15 Heads and 15 Tails.

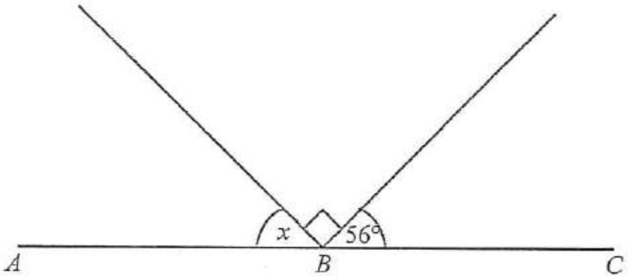
....

....

(1)

Shapes, Space and Measures

1.



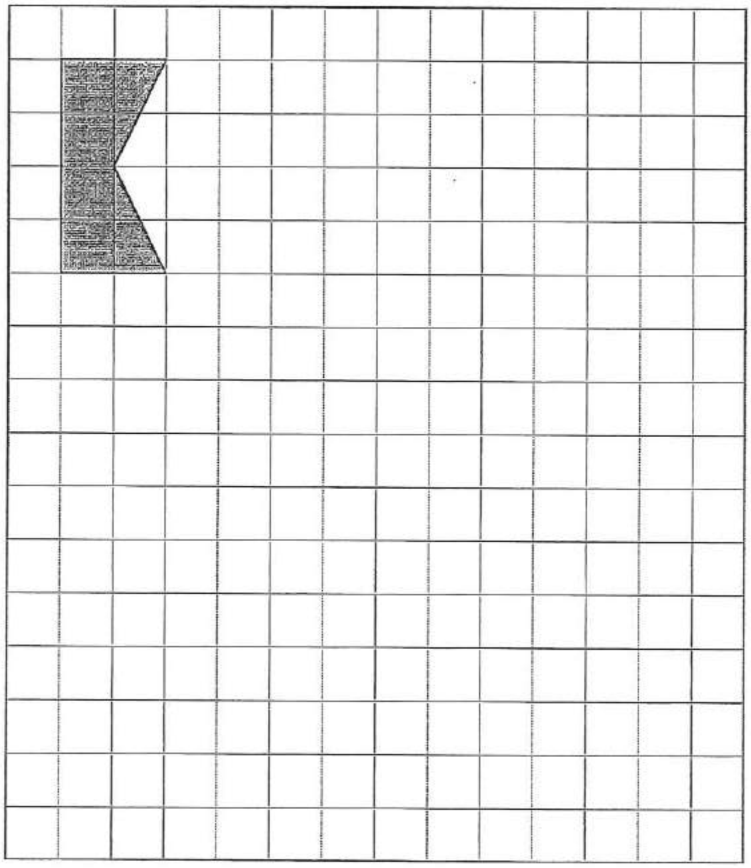
ABC is a straight line.

Work out the size of angle x.
Give a reason for your answer.

..................................°

(Total 3 marks)

2.



On the grid, draw an enlargement of the shape with a scale factor of 2.

(Total 2 marks)

3. A cuboid has

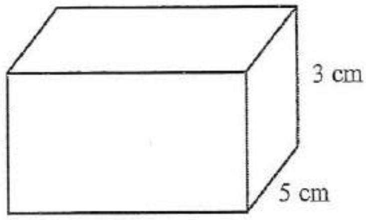


Diagram **NOT** accurately drawn

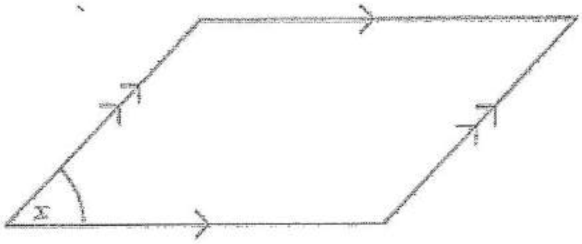
a length of 10 cm, a width of 5 cm, a height of 3 cm.

Work out the volume of the cuboid.

.... cm^3

(Total 2 marks)

4.



(a) Write down the name of this quadrilateral.

....

(1)

(b) Mark, with the letter B, an obtuse angle.

(1)

(c) Write down an estimate for the size of the angle marked x.

..........................°

(1)

(Total 3 marks)

5.

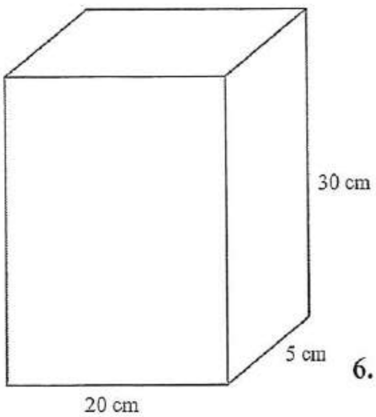


Diagram **NOT** accurately drawn

The diagram shows a cuboid.

Work out the volume of the cuboid.

.... cm^3

(Total 2 marks)

6.

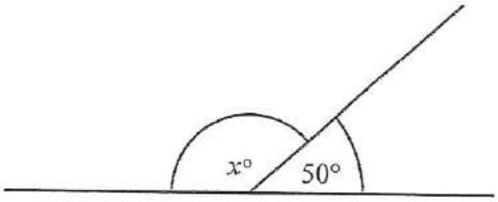


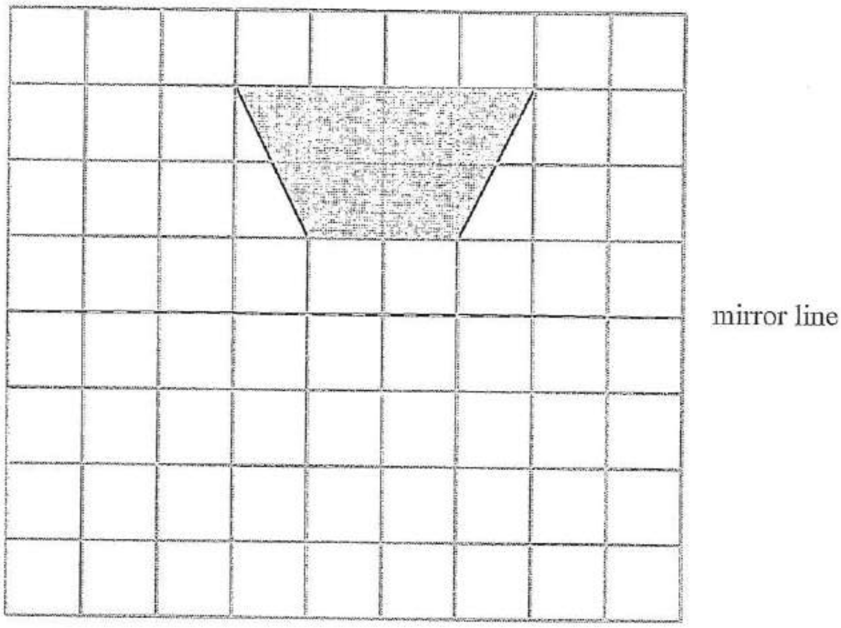
Diagram **NOT** accurately drawn

Work out the size of the angle marked $x°$.

……………………..°

(Total 2 marks)

7.



Reflect the shaded shape in the mirror line.

(Total 1 mark)

8.

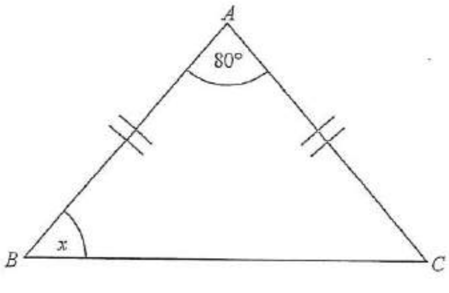


Diagram **NOT** accurately drawn

ABC is an isosceles triangle.

The angle marked x is 50°
Give reasons why.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

(Total 2 marks)

Science
Year 10

Contents

C 4 Chemical calculations

4.1 Relative masses and moles

Learning objectives

After this topic, you should know:

- what is meant by the relative atomic mass of an element
- how to calculate the relative atomic mass of an element and the relative formula mass of a compound
- (H) how to calculate the number of moles, given the mass (or the mass, given the number of moles) of substance.

Calculating relative atomic mass

You can calculate the relative atomic mass A_r of an element given the percentage abundance of its isotopes, for example, copper has two isotopes, ^{63}Cu (abundance = 69%) and ^{65}Cu (31%).

To work out the relative atomic mass of copper from this data, imagine you had 100 copper atoms. 69 copper atoms would have a relative mass of 63, and the other 31 copper atoms would have a mass of 65. Then calculate the mean relative mass of these 100 atoms:

$$A_r \text{ of Cu} = \frac{(69 \times 63) + (31 \times 65)}{100} = 63.5$$

Relative formula mass

You also need to know how to work out the relative formula mass of more complex ionic compounds such as aluminium sulfate, $Al_2(SO_4)_3$.

Aluminium has an A_r of 27, the A_r of sulfur is 32, and the A_r of oxygen is 16. In this case, you must multiply any atoms *within* the brackets by the subscript number *after* the brackets. This means that the M_r of aluminium sulfate is:

$$(27 \times 2) + (32 \times 3) + (16 \times 12)$$
$$= 54 + 96 + 192 = 342$$

Relative atomic masses

The mass of a single atom is so tiny that it would not be practical to use it in experiments or calculations. So instead of working with the actual masses of atoms, the *relative* masses of atoms of different elements are used. These are called **relative atomic masses A_r**.

On any relative scale you need a standard reference point to compare against. In quoting relative atomic masses, the atom of carbon-12, $^{12}_{6}C$, is used as a standard atom. Carbon-12 is given a 'mass' of exactly 12 units because it has six protons and six neutrons. You can then compare the masses of atoms of all the other elements with this standard carbon atom. For example, hydrogen has a relative atomic mass of 1, as most of its atoms have a mass that is $\frac{1}{12}$ of the mass of a $^{12}_{6}C$ atom.

The A_r takes into account the proportions of any isotopes of the element found naturally. So it is the mean (average) relative mass of the isotopes of an element compared with the standard carbon atom. That is why chlorine has a relative atomic mass of 35.5, although you could never have half a proton or neutron in an atom.

Relative formula masses

You can use the A_r of the various elements to work out the **relative formula mass M_r** of compounds. This is true whether the compounds are made up of molecules or ions.

A simple example is a substance such as sulfuric acid, H_2SO_4. Hydrogen has an A_r of 1, the A_r of sulfur is 32, and the A_r of oxygen is 16. This means that the M_r of sulfuric acid is:

$$(1 \times 2) + 32 + (16 \times 4) = 2 + 32 + 64 = 98$$

In the case of molecular substances, such as H_2SO_4, the relative formula mass can also be referred to as the relative molecular mass.

The mole

Higher

Saying or writing 'relative atomic mass in grams' or 'relative formula mass in grams' is rather clumsy. So chemists have a shorthand word to describe this amount of substance – a **mole**. The abbreviation used for mole is mol. The relative atomic mass in grams of carbon (i.e., 12 g of carbon) is a mole of carbon atoms. One mole is simply the relative atomic mass or relative formula mass of any substance expressed in grams.

A mole of any substance always contains the same number of atoms, molecules, or ions. This is a huge number and its value is called the **Avogadro constant**. In standard form, it is written as 6.02×10^{23} per mole. In fact, if you had as many soft drink cans as there are atoms, molecules, or ions in a mole, they would cover the surface of the Earth to a depth of 200 miles.

Higher

Moles from masses

Chemists prefer to use the mole when describing relative numbers of particles (atoms, molecules, or ions) in a certain mass of substance. They use the equation:

$$\textbf{number of moles} = \frac{\text{mass (g)}}{A_r} \quad \text{or} \quad \frac{\text{mass (g)}}{M_r}$$

Masses from moles

Sometimes you will have to work out the mass of a substance from a given number of moles.

By re-arranging:

$$\text{number of moles} = \frac{\text{mass (g)}}{A_r} \quad \text{or} \quad \frac{\text{mass (g)}}{M_r}$$

you can calculate the mass of a certain number of moles of substance using the equation:

mass (g) = **number of moles** $\times A_r$ or **number of moles** $\times M_r$

Synoptic links

For more information on standard form, see Topic C1.7 and Maths skills M1b. To revise significant figures, see Maths skills M2a.

Synoptic link

To revise isotopes, look back to Topic C1.7.

Worked example: Calculating moles

How many moles of sulfuric acid molecules are there in 4.9 g of sulfuric acid?

Solution

number of moles of H_2SO_4 molecules $= \frac{4.9}{98} = 0.20$ mol

The answer is given as 0.20 mol, as opposed to 0.2 mol. This is because the data in the question was provided to 2 significant figures, so the answer should also be given to 2 significant figures.

Worked example: Calculating mass

What is the mass of 7.5×10^{-3} moles of aluminium sulfate?

Solution

mass of $Al_2(SO_4)_3 = (7.5 \times 10^{-3}) \times 342 = 2.6$ g

The number that appears on your calculator is 2.565. This is quoted to 4 significant figures. In the question, 7.5×10^{-3} moles, is only given to 2 significant figures, so the answer should reflect this. Hence 2.565 is rounded up to 2.6.

1 What is the relative atomic mass of an element? [2 marks]

2 What is the relative formula mass of:

a MgF_2 (A_r values: Mg = 24, F = 19) [1 mark]

b $C_6H_{12}O_6$ (A_r values: C = 12, H = 1, O = 16)? [1 mark]

3 (H) a How many moles of helium atoms are there in 0.02 g of helium? [1 mark]

b How many moles of sulfur atoms are there in:

i 9.6 g of sulfur [1 mark]

ii 16 tonnes of sulfur (where 1 tonne = 1000 kg)? [1 mark]

4 (H) What is the mass of:

a 50 moles of calcium carbonate, $CaCO_3$ [1 mark]

b 0.05 moles of hydrogen, H_2 [1 mark]

c 0.6 moles of phosphorus, P_4? [1 mark]

5 Why can you have relative atomic masses, which are not whole numbers, e.g., the A_r of chlorine, Cl, is 35.5. [1 mark]

Key points

- The masses of atoms are compared by measuring them relative to atoms of carbon-12.
- You can work out the relative formula mass of a compound by adding up the relative atomic masses of the elements in it, in the ratio shown by its formula.
- (H) One mole of any substance is its relative formula mass, in grams.
- (H) number of moles $= \frac{\text{mass (g)}}{A_r}$ or $\frac{\text{mass (g)}}{M_r}$
- (H) Avogadro constant is 6.02×10^{23} per mole.

C4.2 Equations and calculations

Learning objectives

After this topic, you should know:

- what balanced symbol equations tell you about chemical reactions
- how to use balanced symbol equations to calculate masses of reactants and products.

Study tip

The '2' inserted in front of HCl to balance the equation is called a multiplier.

Fractions in equations

Sometimes you will see fractions written in balanced equations. Even though you cannot have half an atom, ion, or molecule, you can read these equations as half a mole of the substance. These fractions are usually used in combustion reactions, such as:

$$C_2H_6 + 3\tfrac{1}{2}\,O_2 \rightarrow 2CO_2 + 3H_2O$$

Here you have two moles of carbon atoms, six moles of hydrogen atoms, and seven moles of oxygen atoms on both sides of the balanced equation.

By multiplying all the large numbers (multipliers) in the equation by 2 you will get all whole numbers and maintain a balanced equation:

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

Chemical equations can be very useful. When you want to know how much of each substance is involved in a chemical reaction, you can use the balanced symbol equation.

Think about what happens when hydrogen molecules, H_2, react with chlorine molecules, Cl_2. The reaction makes hydrogen chloride molecules, HCl:

$$H_2 + Cl_2 \rightarrow HCl \qquad \text{(not balanced)}$$

This equation shows the reactants and the product – but it is not balanced.

Here is the balanced equation:

$$H_2 + Cl_2 \rightarrow 2HCl$$

This balanced equation tells you that one hydrogen molecule reacts with one chlorine molecule to make two hydrogen chloride molecules. The balanced equation also tells you the number of moles of each substance involved. It tells you that 1 mole of hydrogen molecules reacts with 1 mole of chlorine molecules to make 2 moles of hydrogen chloride molecules.

one hydrogen molecule		one chlorine molecule		two hydrogen chloride molecules
H_2	+	Cl_2	$\rightarrow$	2HCl
1 mole of hydrogen molecules		1 mole of chlorine molecules		2 moles of hydrogen chloride molecules

Using balanced equations to work out reacting masses

The balanced equation above is really useful because you can use it to work out what mass of hydrogen and chlorine react together. You can also calculate how much hydrogen chloride is made.

Worked example 1

What masses of reactants and products are involved in the balanced symbol equation:

$$H_2 + Cl_2 \rightarrow 2HCl$$

Solution

To do this, you need to know that the A_r for hydrogen is 1 and the A_r for chlorine is 35.5.

A_r of hydrogen = 1 mass of 1 mole of $H_2 = 2 \times 1 = 2$ g

A_r of chlorine = 35.5 mass of 1 mole of $Cl_2 = 2 \times 35.5 = 71$ g

M_r of HCl = (1 + 35.5) mass of 1 mole of HCl = 36.5 g

The balanced equation tells you that one mole of hydrogen reacts with one mole of chlorine to give two moles of hydrogen chloride molecules. So turning this into masses you get:

1 mole of hydrogen molecules, H_2	$= 1 \times 2$	$= 2$ g
1 mole of chlorine molecules, Cl_2	$= 1 \times 71$	$= 71$ g
2 moles of hydrogen chloride molecules, 2HCl	$= 2 \times 36.5$	$= 73$ g

More reacting mass calculations

These calculations are important when you want to know the mass of chemicals that react together.

Worked example 2

Sodium hydroxide reacts with chlorine gas to make bleach. This reaction happens when chlorine gas is bubbled through a solution of sodium hydroxide. The balanced symbol equation for the reaction is:

$$2NaOH + Cl_2 \rightarrow NaOCl + NaCl + H_2O$$

sodium hydroxide   chlorine   bleach   salt   water

If you have a solution containing 100.0 g of sodium hydroxide, what mass of chlorine gas do you need to convert it to bleach?

Solution

A_r values: hydrogen = 1, oxygen = 16, sodium = 23, chlorine = 35.5

Mass of 1 mole of	
NaOH	Cl_2
$= 23 + 16 + 1 = 40$ g	$= 35.5 \times 2 = 71$ g

The table shows that 1 mole of sodium hydroxide has a mass of 40 g.

So 100.0 g of sodium hydroxide is $\frac{100}{40} = 2.5$ moles.

The balanced symbol equation tells you that for every 2 moles of sodium hydroxide you need 1 mole of chlorine to react with it.

So you need $\frac{2.5}{2} = 1.25$ moles of chlorine.

The table shows that 1 mole of chlorine has a mass of 71 g.

So you will need $1.25 \times 71 = 88.75$ g of chlorine to react with 100.0 g of sodium hydroxide.

The answer 88.75 g is given to 4 significant figures. This is to be consistent with the data supplied in the question, as you started with 100.0 g of sodium hydroxide.

The number of significant figures to which the relative atomic masses are quoted does not need to be taken into account in chemical calculations.

Key points

- Balanced symbol equations tell you the number of moles of substances involved in a chemical reaction.
- You can use balanced symbol equations to calculate the masses of reactants and products in a chemical reaction.

1 2HCl can have two meanings. What are they? [1 mark]

2 Magnesium burns in oxygen with a bright white flame:
$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$
What mass of oxygen will react exactly with 6.0 g of magnesium?
(A_r values: O = 16, Mg = 24) [2 marks]

3 a An aqueous solution of hydrogen peroxide, H_2O_2, decomposes to form water and oxygen gas. Write a balanced symbol equation, including state symbols, for this reaction. [3 marks]

b When hydrogen peroxide decomposes, what mass of hydrogen peroxide is needed in solution to produce 1.6 g of oxygen gas? [2 marks]

4 When a small lump of calcium metal, Ca, is added to water, it reacts giving off hydrogen gas. A solution of calcium hydroxide, $Ca(OH)_2$, is also formed in the reaction.

a Write a balanced symbol equation, including state symbols, for the reaction. [3 marks]

b Calculate how much calcium metal must be added to an excess of water to produce 3.7 g of calcium hydroxide. [2 marks]

C4.3 From masses to balanced equations

Learning objectives

After this topic, you should know:

- how to balance an equation, given the masses of reactants and products
- why a limiting quantity of a reactant affects the amount of product it is possible to obtain (in terms of amounts in moles or masses in grams).

Synoptic link

You first met the Law of conservation of mass in Topic C1.2.

In Topic C4.2 you saw how to use a balanced chemical equation to calculate the mass of reactants and products in a reaction. Alternatively, if you have the masses of the substances involved in a reaction, you can work out the ratio of the number of moles of each reactant and product (called the stoichiometry of the reaction). The simplest whole-number ratio gives you the balanced equation.

Worked example 1

Sodium nitrate, $NaNO_3$, decomposes on heating to give sodium nitrite, $NaNO_2$, and oxygen gas, O_2.

When 8.5 g of sodium nitrate is heated in a test tube until its mass is constant, 6.9 g of sodium nitrite is produced.

a What mass of oxygen must have been given off in the reaction?

b Find the ratio of reactants and products involved in the reaction, and show how these can be used to produce the balanced symbol equation for the decomposition of sodium nitrate:

(A_r values: Na = 23, N = 14, O = 16)

Solution

a You know that the total mass of reactants = total mass of products (from the Law of conservation of mass). So if the mass of oxygen is x g:

sodium nitrate → sodium nitrite + oxygen

$$8.5\,g = 6.9\,g + x\,g$$

$(8.5 - 6.9)\,g = x\,g$

$1.6\,g$ = mass of oxygen

b From the masses given in the question and our answer to part a, you can work out the numbers of moles of each reactant and product:

First of all, you will need to calculate the relative formula masses M_r of the reactants and products using the A_r values provided:

M_r of $NaNO_3 = [23 + 14 + (16 \times 3)] = 85$

M_r of $NaNO_2 = 69$

M_r of $O_2 = 32$

Then use the equation from Topic C4.1 to convert masses to moles:

$$\text{number of moles} = \frac{\text{mass}}{M_r}$$

moles of $NaNO_3 = \frac{8.5}{85} = 0.1$ mol   moles of $NaNO_2 = \frac{6.9}{69} = 0.1$ mol   moles of $O_2 = \frac{1.6}{32} = 0.05$ mol

Then find the simplest whole-number ratio of the numbers of moles of $NaNO_3 : NaNO_2 : O_2$

moles of $NaNO_3 : NaNO_2 : O_2$

0.1 : 0.1 : 0.05

Dividing the ratio by the smallest number gives:

2 : 2 : 1

So the balanced equation is:

$2NaNO_3 \rightarrow 2NaNO_2 + O_2$

Limiting reactants

More often than not, when you carry out a reaction in experiments, you do not use the exact amounts of reactants as predicted in the balanced equation. One of the reactants will be in excess. For example, if you add dilute hydrochloric acid to magnesium ribbon, hydrogen gas is given off and you see bubbles rising from the magnesium. If the reaction stops (no more bubbles of gas appear) but there is still magnesium ribbon – the magnesium is in excess. The reason the reaction stops is that all the acid has been used up. In this case the hydrochloric acid is called the **limiting reactant**. What would you expect to see at the end of the reaction if the magnesium was the limiting reactant?

The reactant that gets used up first in a reaction is called the limiting reactant (or limiting reagent).

You can work out which is the limiting reactant from the balanced equation, if you know the number of moles of reactants you start with.

Worked example 2

If you have 4.8 g of magnesium ribbon reacting in a solution of dilute hydrochloric acid containing 7.3 g of HCl, which reactant is the limiting reactant?

(A_r values: Mg = 24, H = 1, Cl = 35.5)

Solution

The balanced equation for the reaction is:

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

You are only interested in the reactants in this question.

number of moles $= \frac{\text{mass}}{A_r}$ or $\frac{\text{mass}}{M_r}$

You start with 4.8 g of Mg, which is $\frac{4.8}{24}$ moles = 0.2 mol

and 7.3 g of HCl, which is $\frac{7.3}{(1 + 35.5)}$ moles $= \frac{7.3}{36.5} = 0.2$ mol

From the balanced equation, you see that 1 mole of Mg will react with 2 moles of HCl.

Therefore 0.2 mol of Mg will need 0.4 mol of HCl to react completely. In this case, we have not got 0.4 mol of HCl – we only have 0.2 mol – so the dilute hydrochloric acid is the limiting reactant (and the magnesium is in excess).

Key points

- You can deduce balanced symbol equations from the masses (and hence the ratio of the numbers of moles) of substances involved in a chemical reaction.
- The reactant that gets used up first in a reaction is called the limiting reactant. This is the reactant that is NOT in excess.
- Therefore, the amounts of product formed in a chemical reaction are determined by the limiting reactant.

1 State what we mean by a limiting reactant in a chemical reaction. [1 mark]

2 When copper metal reacts with oxygen gas, black copper oxide, CuO, is formed. In an experiment it was found that when copper reacted completely with oxygen, 6.35 g of copper reacted with 1.60 g of oxygen gas, O_2, to form 7.95 g of copper oxide.
   a Calculate the number of moles of each reactant and product. [3 marks]
   b Show how this relates to the balanced symbol equation for the reaction. [2 marks]

3 Aluminium reacts with iron(III) oxide, Fe_2O_3, to give iron metal and aluminium oxide, Al_2O_3.
   a Write a balanced symbol equation for this reaction. [3 marks]
   b In an experiment, 32.0 g of iron(III) oxide was reacted with 16.2 g of aluminium. Which of the two reactants is the limiting reactant? Show your working. [2 marks]
   c Calculate the maximum mass of iron that could be collected at the end of this experiment. [2 marks]

C4.4 Expressing concentrations

Learning objectives

After this topic, you should know:

- the concentration of solutions can be expressed in grams per dm^3 (g/dm^3)
- **H** how the mass of a solute and the volume of a solution is related to the concentration of the solution.

Figure 1 *The orange squash is getting less concentrated going left to right (the darker colour indicates more squash is in the same volume of its solution)*

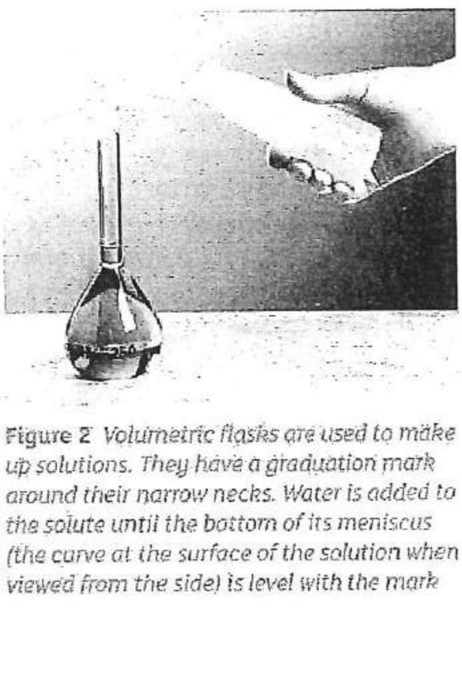


Figure 2 *Volumetric flasks are used to make up solutions. They have a graduation mark around their narrow necks. Water is added to the solute until the bottom of its meniscus (the curve at the surface of the solution when viewed from the side) is level with the mark*

What is the concentration of a solution?

When you make a drink of orange squash, sometimes you put too much squash in the glass – sometimes you add too much water. Then you can add more water or add more squash until the colour looks right for you. A chemist would say that you are adjusting the **concentration** of the solution.

Chemists often carry out their reactions in solution. The solvent is usually water but can be other liquids, such as ethanol.

To record, interpret, and communicate their results, they need to express the concentration of the solutions they use. Other chemists should be able to repeat published experiments to verify data. So chemists quote the amount of substance (solute) dissolved in a certain volume of the solution. The units they use to express the concentration of a solution can be grams per decimetre cubed (g/dm^3). A decimetre cubed ($1\ dm^3$) is equal to $1000\ cm^3$.

Calculating concentrations

If you know the mass of solute dissolved in a certain volume of solution, you can work out its concentration.

As an equation:

$$\textbf{concentration (g/dm}^3\textbf{)} = \frac{\textbf{amount of solute (g)}}{\textbf{volume of solution (dm}^3\textbf{)}}$$

If you are working in centimetres cubed (cm^3), convert the volume to dm^3 by dividing it by 1000, and use the equation above. Alternatively, substitute your data in cm^3 into the following equation:

$$\textbf{concentration (g/dm}^3\textbf{)} = \frac{\textbf{amount of solute (g)}}{\textbf{volume of solution (cm}^3\textbf{)}} \times 1000$$

As an example, imagine that you make a solution of sodium hydroxide in water. You dissolve exactly 40.0 g of sodium hydroxide in enough water to make exactly $3.00\ dm^3$ of solution. You can calculate the concentration of the solution in g/dm^3:

$$\frac{40.0\ g}{3.0\ dm^3} = 13.3\ g/dm^3.$$

Worked example: Concentration of a solution

50 g of sodium hydroxide is dissolved in water to make up $200\ cm^3$ of solution. What is its concentration, given in g/dm^3? (Remember that $1\ dm^3 = 1000\ cm^3$.)

Solution

To find the concentration of the solution, you should use the equation:

$$\text{concentration g/dm}^3 = \frac{\text{amount of solute (g)}}{\text{volume of solution (cm}^3\text{)}} \times 1000$$

So, $\frac{50\text{ g}}{200\text{ cm}^3} = 0.25$

$0.25\text{ g/cm}^3 \times 1000 = 250\text{ g/dm}^3$

If you know the concentration of a given volume of solution you can calculate the amount of solute in the solution.

Worked example: Calculating mass of solute

A solution of sodium chloride has a concentration of 200 g/dm^3. What is the mass of sodium chloride in 700 cm^3 of the solution?

Solution

First, you need to convert 700 cm^3 into dm^3.

$\frac{700}{1000} = 0.7\text{ dm}^3$

Then rearrange the equation to make amount of solute (g) the subject.

amount of solute (g) = concentration (g/dm^3) × volume of solution (dm^3)

So, $200\text{ g/dm}^3 \times 0.7 = 140\text{ g}$

Higher

You can increase the concentration of an aqueous solution by:

- adding more solute and dissolving it in the same volume of its solution
- evaporating off some of the water from the solution so you have the same mass of solute in a smaller volume of solution.

1 Calculate the concentration in g/dm^3 for:
  a 50 g of sodium chloride in 2.5 dm^3 of water. [1 mark]
  b 1.8 g of sodium carbonate in 862 cm^3 of water. [1 mark]

2 A technician made up a solution of potassium hydroxide, KOH, by placing 7.00 g of solid potassium hydroxide into a volumetric flask and added water up to 100 cm^3 mark. She then stoppered the flask and shook the solution until the potassium hydroxide had dissolved completely. What was the concentration of the solution in g/dm^3? [1 mark]

3 (H) Explain how the mass of a solute and the volume of water affect the concentration of a solution. [2 marks]

4 A student had a solution of sodium chloride with a concentration of 93.6 g/dm^3 sodium. Calculate the mass of sodium chloride dissolved in 25.0 cm^3 of the solution. [2 marks]

Study tip

Make sure you are using the correct equation for concentration, depending on the units for volume used.

Key points

- concentration (g/dm^3) $= \frac{\text{amount of solute (g)}}{\text{volume of solution (dm}^3\text{)}}$
- To calculate the mass of solute in a certain volume of solution of known concentration:
  1 Calculate the mass (in grams) of the solute there is in 1 dm^3 (1000 cm^3) of solution.
  2 Calculate the mass (in grams) of solute in 1 cm^3 of solution.
  3 Calculate the mass (in grams) of solute there is in the given volume of the solution.
- (H) A more concentrated solution has more solute in the same volume of solution than a less concentrated solution.

C4 Chemical calculations

Summary questions

1 Calculate the relative formula mass M_r of each of the following compounds:

a H_2S	[1 mark]	e Na_2CO_3	[1 mark]
b SO_2	[1 mark]	f $Al_2(SO_4)_3$	[1 mark]
c C_2H_4	[1 mark]	g $NaAl(OH)_4$	[1 mark]
d NaOH	[1 mark]		

(H) 2 How many moles of:

a Ag atoms are there in 27 g of silver [1 mark]

b Fe atoms are there in 0.056 g of iron [1 mark]

c P_4 molecules are there in 6.2 g of phosphorus? [1 mark]

3 (H) In a lime kiln, calcium carbonate is decomposed to calcium oxide:

$$CaCO_3 \rightarrow CaO + CO_2$$

Calculate the maximum mass of calcium oxide that 1500 tonnes of calcium carbonate can produce. [2marks]

4 a Ethene gas, C_2H_4, reacting with steam, H_2O, to form ethanol gas, C_2H_5OH, is a reversible reaction. Write the balanced symbol equation for this reaction, including state symbols. [1 mark]

(H) b 14.00 g of ethene is reacted with excess steam. Calculate the maximum mass of ethanol that can be produced, assuming 100% conversion of reactants to product.

(H) 5 Sulfur is mined in Poland and is brought to Britain in ships. The sulfur is used to make sulfuric acid. Sulfur is burnt in air to produce sulfur dioxide. Sulfur dioxide and air are passed over a heated catalyst to produce sulfur trioxide. Water can be added to sulfur trioxide to produce sulfuric acid. The reactions are:

$$S + O_2 \rightarrow SO_2$$
$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$
$$SO_3 + H_2O \rightarrow H_2SO_4$$

(A_r values: H = 1, O = 16, S = 32)

a How many moles of sulfuric acid could be produced from one mole of sulfur? [1 mark]

b Calculate the maximum mass of sulfuric acid that can be produced from 64 kg of sulfur. [2 marks]

(H) 6 a There are 6.02×10^{23} atoms of carbon in 12.0 g of carbon.
How many individual carbon atoms are there in 96.0 g of carbon, C? [1 mark]

b Which has more atoms – 96.0g of carbon, C, or 32.0 g of helium, He? Show your working out. [2 marks]

c What is the name and unit of the constant that tells us the number of atoms of carbon in 12.0 g of carbon? [1 mark]

d Calculate the mass of the following amounts of substance, giving your answers to an appropriate number of significant figures:

i 0.650 mol silicon, Si

ii 4.87 mol iron, Fe

iii 3.00×10^{-3} mol hydrogen, H_2

iv 0.0770 mol potassium nitrate, KNO_3

e Calculate the concentration of the following solutions in g/dm³. Give your answers to an appropriate number of significant figures:

i 2.525 g of potassium nitrate, $Mg(NO_3)_2$, dissolved in 50 cm³ of solution

ii 2.925×10^{-4} g of sodium chloride, NaCl, in 5 cm³ of solution.

7 Magnesium carbonate, $MgCO_3$, decomposes when heated in a similar reaction to calcium carbonate.

a Write a balanced symbol equation for the decomposition of magnesium carbonate. [1 mark]

(H) b When a sample of magnesium carbonate was decomposed, 1.10 g of carbon dioxide gas was given off. Calculate the number of moles of carbon dioxide gas given off. [1 mark]

(H) c What mass of magnesium carbonate was decomposed in the reaction? [1 mark]

(H) d Magnesium carbonate also reacts with dilute hydrochloric acid:

$$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$$

i What is the easiest way to tell when this reaction has finished? [1 mark]

ii 8.4 g of magnesium carbonate was added to 25 cm³ dilute hydrochloric acid with a concentration of 7.3 g/dm³. Show which reactant is the limiting reactant. [4 marks]

iii Calculate the mass of carbon dioxide gas given off in the reaction described in part ii. [1 mark]

8 Calculate the relative atomic mass of:

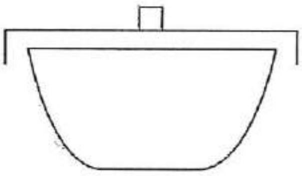
a bromine (made up of 50% ^{79}Br and 50% ^{81}Br) [1 mark]

b iron (with 5.8% ^{54}Fe, 91.8% ^{56}Fe, 2.1% ^{57}Fe and 0.3% ^{58}Fe). [2 marks]

Practice questions

01 This question is about the change in mass when chemical reactions take place in a crucible.
A crucible has a loose lid so that gases can get in or get out. A diagram of a crucible is shown in **Figure 1**.

Figure 1



01.1 A student heated a piece of magnesium in a crucible. The magnesium reacts as shown in the equation. Balance the equation.
.... $Mg(s) + O_2(g) \rightarrow$ .... $MgO(s)$ [2 marks]

01.2 The student recorded the masses shown in **Table 1**.

Table 1

	Mass in g
Mass of crucible at the start of the reaction	0.24
Mass of crucible at the end of the reaction	0.40

Explain why the mass increased. [2 marks]

01.3 The student heated the crucible again at the end of the reaction. What could the student do to make sure the reaction was complete? [2 marks]

01.4 Another student heated lithium carbonate in a crucible. The lithium carbonate reacts as shown in the equation.
$Li_2CO_3(s) \rightarrow Li_2O(s) + CO_2(g)$
Use the equation to predict whether the mass would increase or decrease. Explain your answer.
[3 marks]

H 02 This question is about the combustion of hydrocarbons.

02.1 0.010 moles of hydrocarbon **Z** are burnt completely in an excess of oxygen. The equation for the reaction is below.
$C_xH_y + O_2(g) \rightarrow$ ....$CO_2(g)$ + ...H_2O
1.76 g of carbon dioxide and 0.90 g of water are produced.
Use this information to work out the balancing numbers for CO_2 and H_2O.
Relative atomic masses: C = 12; H = 1; O = 16
[4 marks]

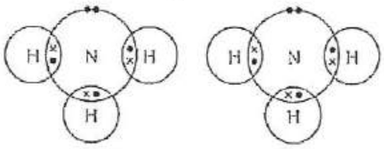
02.2 Use your answer from 02.1 to work out the identity of hydrocarbon **Z**. Tick (✓) the correct answer

C_2H_4	
C_3H_8	
C_4H_{10}	
C_8H_{16}	

[1 mark]

H 03 This question is about the manufacture of ammonia. Ammonia is made from nitrogen and hydrogen as shown in the equation.
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$
Two molecules of ammonia are shown in **Figure 2**.

Figure 2



Ammonia is a gas at room temperature because it has a low boiling point.

03.1 Explain why ammonia has a low boiling point. You should refer to **Figure 2** in your answer. [2 marks]

03.2 84 tonnes of nitrogen were mixed with 30 tonnes of hydrogen.
Relative atomic masses: N = 14; H = 1.
1 tonne = 1 000 000 g.
Calculate the number of moles of nitrogen and the number of moles of hydrogen, and show that nitrogen is the limiting reactant. [3 marks]

03.3 Calculate the maximum mass of ammonia that can be produced from 84 tonnes of nitrogen.
[3 marks]

04 Calcium reacts with water forming calcium hydroxide and hydrogen.

04.1 Balance the equation [1 mark]
Ca + ...$H_2O \rightarrow Ca(OH)_2 + H_2$
The student reacted 5 g of calcium with excess water.

04.2 Calculate the maximum number of moles of hydrogen the student could produce. [2 marks]
In a different experiment a student made 400 cm^3 of a solution of calcium hydroxide of concentration 2.00 g/dm^3.

04.3 Calculate the mass of calcium hydroxide dissolved in this solution. [2 marks]

04.4 Give the name of a group 2 metal that would react more violently with water than calcium. [1 mark]

Mixing, Dissolving and Separating

Ideas you have met before

Carrying out experiments

Scientists gather evidence by carrying out experiments. For the evidence to be useful, the experiment has to be designed and carried out carefully. Results and observations need to be recorded so that patterns can be seen and conclusions drawn.

Heating a liquid

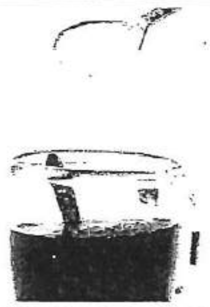
If we heat water enough it will boil and turn into steam. Steam is a gas that, if it cools down, will turn back into a liquid.

Drying involves evaporation, which occurs faster with heat and the movement of air.

Dissolving

Some materials – such as salt and sugar – can dissolve in water. We say that these are soluble.

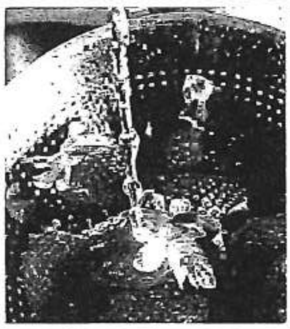
Other materials – such as sand – do not dissolve in water. We say that these are insoluble.



Separating mixtures

If something has been mixed with water but has not dissolved, we can separate it by using a filter or a sieve.

This method can be used to remove sand and gravel from water, but filtering does not remove soluble substances such as salt.

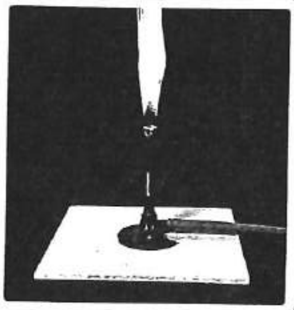


In this chapter you will find out

3.1

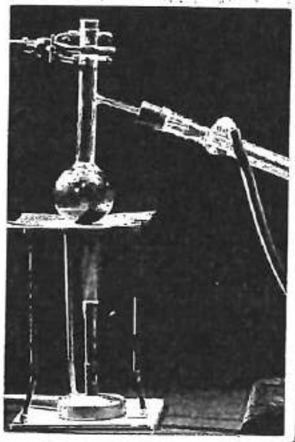
Using laboratory equipment

- A Bunsen burner can be used to supply heat to speed up a chemical reaction or to cause a change of state.
- Measuring the mass before and after a reaction helps us to understand some important ideas in chemistry.



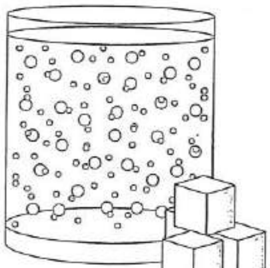
Distillation

- If we heat a liquid it will evaporate, turning into a vapour (gas). If we then cool the vapour, it will turn back into a liquid.
- If we heat different liquids, we find that they boil at different temperatures.
- We can use this information about boiling points to separate mixtures of liquids. The process is called distillation and is used to make perfume and also fuels such as petrol.



Solubility

- When substances dissolve we can explain the process by thinking about the particles they are made of.
- Dissolving often happens more quickly at higher temperatures because of the extra energy of the particles.
- Solutions are very useful.



Chromatography

- Soluble substances can be made to travel up filter paper by adding a solvent.
- If we do this with coloured dyes or inks, we find that the different colours in the mixture move different distances.
- This technique is called paper chromatography and can be used to separate mixtures and identify chemicals.

Working safely in a laboratory

We are learning how to:

- Recognise and reduce risks when working in the laboratory.
- Name and select appropriate equipment.

Many activities that we do are risky – such as crossing the road or playing sport. That does not mean we do not do them, but it is important that we take precautions to reduce the likelihood of injury.

FIGURE 1.3.2a: Head protection makes rollerblading safer, but no less fun.

Staying safe

In many sports – such as cycling, cricket and horse riding – athletes are encouraged to wear head protection. Some jobs require employees to wear special clothing, head, ear or eye protection to minimise the **risk** of injury and keep them safe. Safety is very important in a science **laboratory**.

1. State three jobs that require workers to wear hard hats.
2. Why do doctors and nurses often wear gloves?
3. **a)** What safety equipment is the rollerblader wearing?
   b) List other safety equipment that a competing rollerblader might wear, and how it would protect him/her.

Safety in the laboratory

Ignoring **hazards** can lead to accidents and people being injured. If we identify and reduce the risk of these hazards then we can work safely. Hazards in the laboratory can come from chemicals, glass equipment or hot objects. The way we behave can also affect the risks to ourselves and to others. Wearing safety goggles is important when performing experiments to protect your eyes from splashes and objects that may splinter or produce sparks.

FIGURE 1.3.2b: Students in this laboratory are NOT safe.

4. How many hazards can you identify in Figure 1.3.2b?
5. How could the risk from these hazards be reduced?
6. Write your top ten safety rules for working safely in the laboratory.

Laboratory apparatus

The laboratory, like a kitchen, contains equipment for heating, measuring, mixing and pouring. However, the names for the equipment are different. It is important to use the correct scientific names for practical **apparatus** so that other scientists can copy your methods to compare and verify the results.

Scientists use a **Bunsen burner** to heat substances to very high temperatures. Knowing how to use the burner safely is very important to reduce the risks of injury and fire.

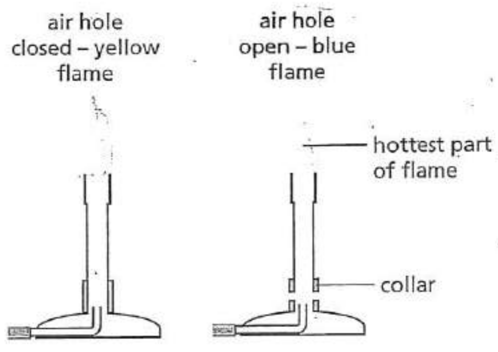


FIGURE 1.3.2c: The flame on a Bunsen burner can be controlled.

A Bunsen has two colours of flame depending on how much air is mixed with the methane gas before it is burned, as shown in Figure 1.3.2c. This is controlled by moving the collar to open and close the air hole at the base. We always leave Bunsen burners with the air hole closed when they are not being used.

7. If you were using a Bunsen burner to heat a liquid in a beaker, why would it be best to:
   a) use a glass beaker, rather than a plastic one?
   b) use a tripod and gauze?
8. Explain how the following apparatus reduces risks in laboratory experiments:
   a) test-tube rack
   b) clamp and stand.
9. Explain how you could reduce the risks when heating a substance in a boiling tube.
10. Give as many advantages as you can for using a heatproof bench mat while heating substances directly in a flame using tongs.

Did you know...?

25 000 children under 5 years old attend hospital in the UK every year after being accidentally poisoned by substances in their own home.

(Royal Society for the Prevention of Accidents)

Key vocabulary

risk

laboratory

hazard

apparatus

Bunsen burner

Recording experiments

We are learning how to:

- Represent scientific experiments clearly.
- Make and record accurate measurements.

Symbols and simple diagrams can accurately represent an object, message or procedure, without requiring the skills of an artist.

Representing apparatus

It is important to be able to represent how an **experiment** has been carried out clearly so that others can understand what has been done. This can be achieved using a simple, common series of 2D images.

An evaporating basin, for example, is represented with a simple 2D **line diagram** (see Figure 1.3.3b). Notice that there is no top line. This shows that the dish is open and has no lid or cover.

You can use the same style of diagram to show how to set up all the apparatus for an experiment.

1. Why are simple 2D diagrams used to represent equipment?
2. Why do scientists use an arrow to represent a Bunsen burner?

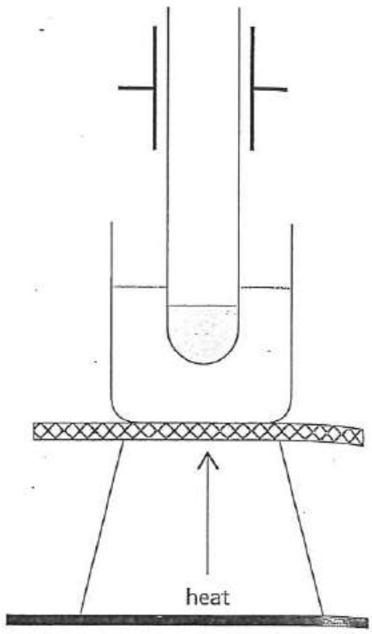


FIGURE 1.3.3a: This type of 2D diagram can be drawn to illustrate apparatus.

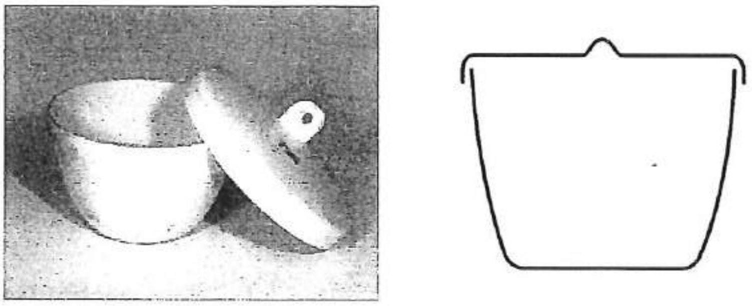


FIGURE 1.3.3b: An evaporating basin and a simple 2D diagram representing it

Measuring accurately

Measuring cylinders come in different sizes – for example 10 cm³, 25 cm³ – so that you can choose the one that most closely matches the volume you are **measuring.** This makes measurements more *accurate* by helping you measure closer to the volume needed.

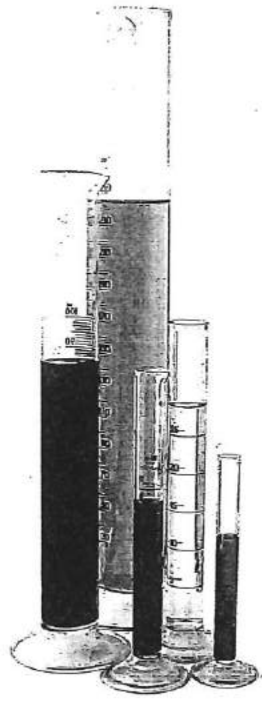


FIGURE 1.3.3c: Measuring cylinders of different sizes

Liquids are not as easy to measure as they may seem because they do not form a straight line at the surface. The surface curves downwards – this is called a **meniscus**. Scientists use the bottom of the meniscus to make their readings. They do this at eye level so that they can be sure that they are reading the position and scale accurately.

Balances can measure mass to different numbers of decimal places. The more decimal places there are the more precise the measurement is and the more *sensitive* the balance is to very small differences in mass.

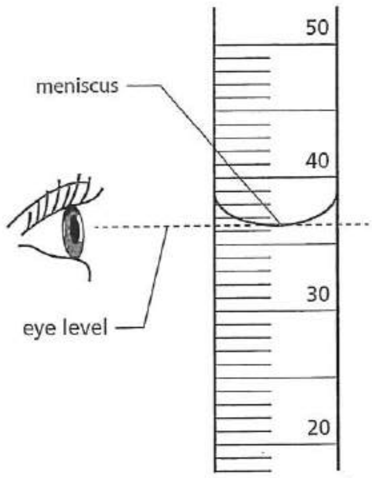


FIGURE 1.3.3d: Reading the meniscus at eye level

3. Explain your choice of equipment to make the following measurements:

a) $6\,cm^3$ **b)** $23\,cm^3$ **c)** 10 g

d) 42.40 g **e)** 20 °C **f)** 62 s

4. Why is it important to choose the appropriate measuring equipment?

Reporting results

Results are recorded in tables with headings, units and **data**. If the mass was measured on a balance with one decimal place, all the data should be reported with one decimal place, including the average result.

Mass of powder	Volume of gas (cm^3)		
	First experiment	Repeated experiment	Average
1 g	5	7	6
10 g	90	95	92.5
5 g	27	23	25

FIGURE 1.3.3e: Example of a results table

5. Say why you think the table in Figure 1.3.3e is a good one and how it could be improved.

6. Write a checklist that your class could use to make sure that your results are recorded accurately.

7. The same $100\,cm^3$ measuring cylinder was used to make all the measurements in the table. How might this have affected the results?

Did you know...?

The meniscus in mercury curves upwards. So, when you read the temperature on a thermometer, you should read the top of the meniscus at eye level.

Key vocabulary

experiment

line diagram

measuring

meniscus

data

Recognising materials, substances and elements

We are learning how to:

- Recognise the difference between materials, substances and elements.
- Identify elements by their names and symbols.
- Explain what is meant by a chemically pure substance.

Chemistry is the study of the structure, properties and uses of materials. Materials are combinations of substances that are made of basic building blocks – the chemical elements.

Elements and compounds

For a scientist, a **material** is anything made of matter or particles. Most materials are made up of combinations of chemical substances, called **compounds**.

Compounds are made up of different **elements**. Elements are the chemical building blocks of materials – each is made up of only one type of atom. Each element is identified by a unique **symbol**, which always begins with a capital letter. Table 1.3.4a lists some common elements and their symbols.

Some elements have symbols based on their old names, such as iron (ferrum), gold (aurum) and copper (cuprum).

1. What is the chemical symbol for carbon?
2. Explain why CO and Co are not the same thing.

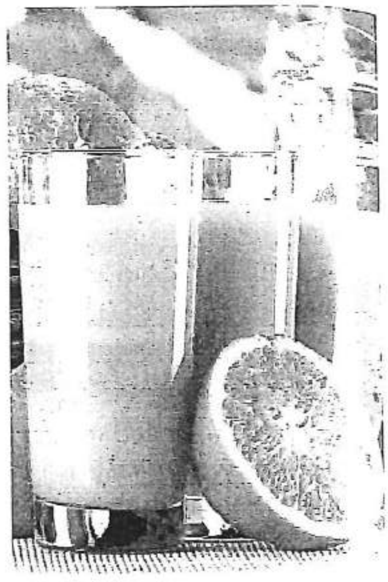


FIGURE 1.3.4a: Orange juice may contain over 10 different compounds, including water, sugar and vitamins.

TABLE 1.3.4a

Name of element	Symbol
hydrogen	H
oxygen	O
carbon	C
cobalt	Co
iron	Fe
gold	Au
copper	Cu
calcium	Ca

Pure or not?

When elements combine in a compound, sometimes they form a **molecule**. A water molecule is made up of two hydrogen (H) atoms and one oxygen (O) atom. We write this as H_2O.

Chemically **pure** water contains only H_2O molecules. Bottled water contains other substances – for example, magnesium (Mg) and calcium (Ca). It is not the same as pure water.

3. Which elements make up the sugar called glucose ($C_6H_{12}O_6$)?
4. Describe the difference between chemically pure water and so-called 'naturally pure' bottled water.

5. Explain why calcium carbonate, $CaCO_3$, is a pure substance but not an element.

6. Why do you think that we call substances like orange juice and bottled water *pure*?

Elements in the body

Almost 99 per cent of the mass of your body is made up of only six elements, but these are combined in different ways. Blood contains water, salts and an iron-containing compound called haemoglobin. Bones and teeth are made from compounds that contain calcium and phosphorus.

In total, your body contains around 28 different elements (Table 1.3.4b) whose atoms combine in various ways to create the different substances that you are made of.

TABLE 1.3.4b

Elements in the human body	Make up (%)
oxygen	65
carbon	18
hydrogen	10
nitrogen	3
calcium	1.5
phosphorus	1.0
potassium	0.35
sulfur	0.25
sodium	0.15
magnesium	0.05
copper, zinc, selenium, molybdenum, fluorine, chlorine, iodine, manganese, cobalt, iron	0.70
lithium, strontium, aluminium, silicon, lead, vanadium, arsenic, bromine	trace amounts

7. Explain why blood is not a pure substance but haemoglobin is.

8. Draw a graph to represent the 10 most abundant elements in your body. Include the symbols.

Did you know…?

Before recorded history, many elements were in use but only in the form of their compounds. It was not until the late 1700s that pure elements started to be isolated and identified.

Key vocabulary

- material
- compound
- element
- symbol
- molecule
- pure

Understanding water

We are learning how to:

- Recognise the importance and different sources of water.
- Explain the differences between types of water.

Approximately 70 per cent of the Earth is covered by water. It exists in oceans, rivers, glaciers and falls from the sky as rain and snow. We rely on it to drink and wash, but also to grow food and to transport us from place to place. It literally sustains life on our planet.

FIGURE 1.3.5a: Much of the Earth is covered by water.

Would you drink seawater?

Seawater tastes salty because of the minerals and salts dissolved in it. Seawater is a **mixture.** It contains substances dissolved from rocks and the atmosphere. Some elements and compounds can be extracted from it and are used to make other things including chlorine, bromine and iodine.

1. Why is seawater described as a mixture?
2. Suggest an easy way of proving that there are substances dissolved in seawater.

What is in our water?

Because **water** is good at dissolving substances, natural sources of water on Earth are mixtures. Even bottled mineral water is not pure water because it contains substances that have been dissolved from the rocks surrounding it. These are not harmful and, in fact, can be good for us.

Some tap water contains a lot of calcium compounds that sometimes appear as a white substance in kettles when the water is boiled – this is called **limescale**. Some of our tap water has fluoride added because it is good for our teeth. Other substances, such as chlorine compounds, are added to kill bacteria and make the water safe to drink.

	(mg/l)
Calcium (Ca)	181.0
Chloride (Cl^-)	57.5
Bicarbonate (HCO_3^-)	239.0
Fluoride (F^-)	0.5
Lithium (Li)	0.2
Magnesium (Mg)	53.5
Nitrate (NO_3^-)	2.2
Potassium (K)	2.5
Silica (SiO_2)	7.5
Sodium (Na)	36.1
Strontium (Sr)	3.2
Sulfate (SO_4^{2-})	459.0

FIGURE 1.3.5b: Bottled water includes substances such as calcium. So does tap water.

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(mg/l)
181.0
57.5
239.0
0.5
0.2
53.5
2.2
2.5
7.5
36.1
3.2
459.0

includes
) does

3. Name two chemicals that might be added to water when it is being prepared to be supplied to us.
4. If there is calcium in the water we drink, how might it have got there?
5. Suggest why drinking water supplied in different parts of the country might taste slightly different.

The need for clean water

Not all countries around the world have access to clean, safe water. In some parts of Africa, for example, many people die due to lack of water or from diseases caught from drinking dirty water. Some African countries are hot, barren and have had significant periods of drought where crops fail and food is scarce. By drilling wells deep underground and providing methods for cleaning and **purifying** water, the lives of people in these areas can be transformed.

FIGURE 1.3.5c: People need clean water.

Our water is recycled. We collect and use rainwater in reservoirs – even the water we flush or wash away is collected and cleaned, and then returned to the main water supply. In order to recycle water effectively, an understanding of chemistry is vital. If too much or the wrong chemical is used, many people would be affected and could be poisoned or become ill from bacteria in the water.

6. Why is a supply of clean water so critical?
7. What is the difference between clean water and pure water?
8. Suggest why the supply of clean water is improved:
   a) in parts of Africa by drilling deep wells
   b) in many countries by building reservoirs.

Did you know...?

Water, H_2O, should be a gas at room temperature, like hydrogen sulfide, H_2S. However, there are special forces between water molecules that hold them together more strongly than molecules in similar compounds.

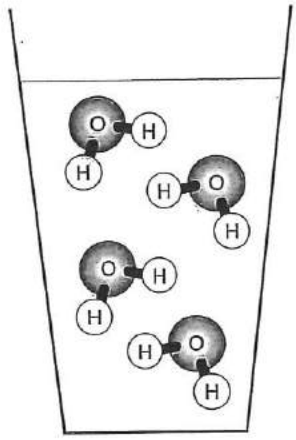

FIGURE 1.3.5d: Water is a special case.

Key vocabulary

mixture

water

limescale

purifying

Dissolving

We are learning how to:

- Explain the terms solvent, solution, solute and soluble.
- Identify factors that affect dissolving.
- Explain the difference between a dilute solution and a concentrated solution.

Limestone caves are amazing places. Stalactites grow down from the roof and, where the water drips down and hits the cave floor, stalagmites grow upwards. They grow only a few centimetres every hundred years as water slowly deposits the minerals it dissolved when passing through the limestone rock.

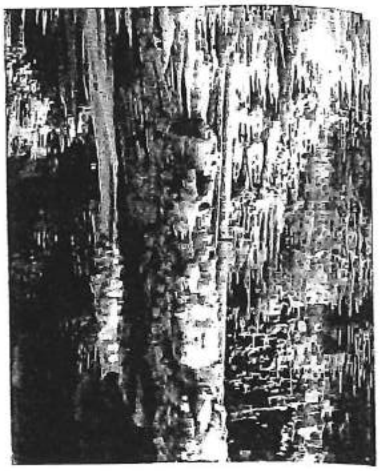

FIGURE 1.3.6a: Even rocks dissolve.

Do you take sugar?

If you stir sugar into a cup of tea or coffee the crystals disappear – they dissolve. The water is called the **solvent** and the mixture is called a **solution**. The sweeter the taste, the more sugar has dissolved. Substances that dissolve are described as **soluble**.

1. Why does sugar disappear when you stir it in tea?
2. How do you know that the sugar is still there in the drink?
3. What is a solution?

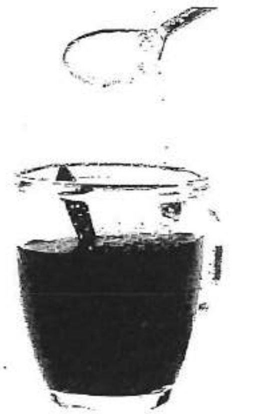

FIGURE 1.3.6b: The sugar seems to disappear but the tea tastes sweet.

Different sugars

Different kinds of sugar all contain sucrose, which is extracted from plants like sugar cane or sugar beet. Although the size of the crystals varies, the sucrose molecules ($C_{12}H_{22}O_{11}$) are all the same.

If you use a beaker containing water you can see how easily sugar dissolves. A solid that dissolves is called a **solute**. Not all types of sugar dissolve in water at the same speed.

FIGURE 1.3.6c: Does the type of sugar affect how it dissolves?

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TABLE 1.3.6: The rate at which different types of sugar dissolve

Sugar type	Mass used (g)	Volume of water (cm^3)	No. of stirs to dissolve it all
caster	1.50	100	20
white cubes	1.50	100	75
granulated	1.45	100	42
brown sugar	1.50	100	58

Look at the experiment results in Table 1.3.6 to answer these questions.

4. What were the solute and the solvent?
5. Put the sugar types in order of size of their sugar pieces, starting with the largest. What do you notice about how they dissolved?
6. Explain why the experiment was a fair test.

Did you know...?

The artificial sweetener aspartame is 250 times sweeter than sucrose. However, a natural sweet protein called thaumatin, found in the West African katemfe fruit, is 3000 times sweeter than sucrose!

Dissolving sugar

Sugar lumps are made of sugar crystals packed together. Each of these crystals contains many tiny sugar molecules. The solution in the glass in Figure 1.3.6d contains a mixture of water molecules (solvent) and sugar molecules (solute).

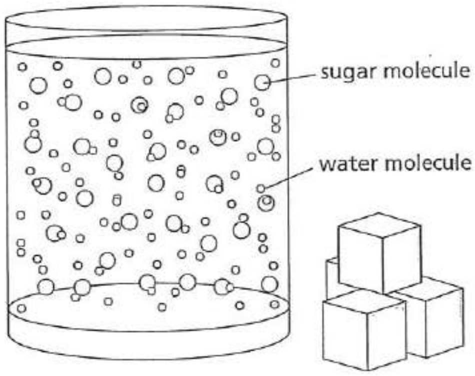


FIGURE 1.3.6d: What happens when sugar dissolves?

The water molecules are much smaller than the original sugar crystals and are able to break down the crystals into sugar molecules. The movement of the water molecules helps to separate and spread the sugar molecules throughout the solution.

The separated molecules are so small that they seem to have disappeared into the water. The mass of sugar dissolved in a particular volume of water is called the **concentration**. If there is a lot of sugar in the water it is a concentrated solution; if there is only a little it is a dilute solution.

7. Explain, using the correct scientific terms, why sugar dissolves.
8. Why does stirring make the sugar dissolve faster?
9. Will icing sugar dissolve faster than caster sugar? Explain your answer.
10. Draw a diagram like the one in Figure 1.3.6d to show the difference between a concentrated solution and a dilute solution.

Key vocabulary

solvent

solution

soluble

solute

concentration

Separating mixtures

We are learning how to:

- Recognise the differences between substances and use these to separate them.

If you put different objects together, such as different fruits in a bowl, toys in a box or sweets in a bag, you have a mixture. Simply picking out one object separates it from the mixture. You can have mixtures of elements and compounds too. These are not so easy to separate.

Using size to separate mixtures

Gravel and rocks can be removed from sand by sieving. This separation depends on the size of the holes in the sieve. However, if the sand was mixed with water, this method would not work. A **filter** would be needed instead.

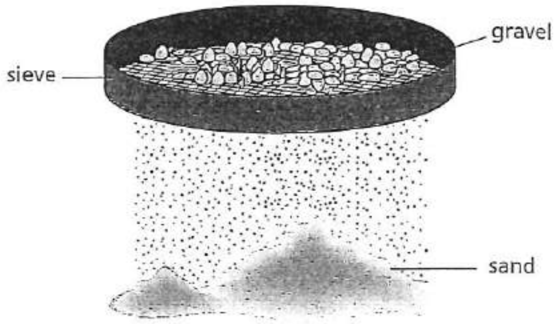


FIGURE 1.3.7a: Using a sieve

Filters are often made of paper or cloth with very small holes that are difficult to see without a microscope. Filters are often used to remove the solids when making coffee. Tea bags act as filters, whereas a tea strainer acts as a sieve. Air and fuel filters are used in cars to remove particles that would damage the engine.

1. What is the difference between a filter and a sieve?
2. Explain how filters and sieves are helpful when making tea and coffee.

Being different

Mixtures can be separated by finding differences between the substances. For example, there are only three metals that are attracted by a magnet – iron, cobalt and nickel. We can use this difference to separate these magnetic metals from mixtures.

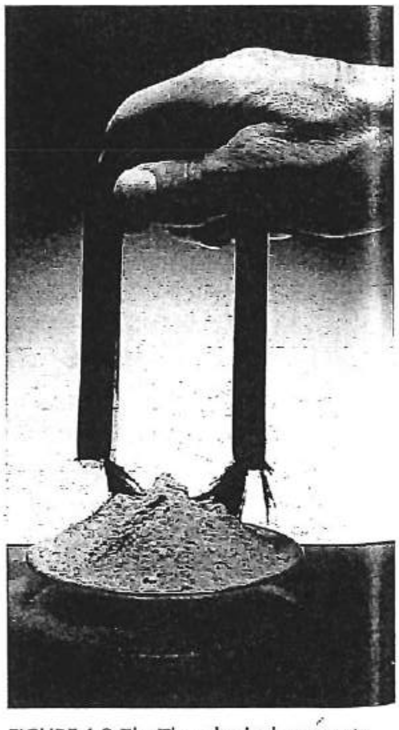


FIGURE 1.3.7b: The physical property of magnetism can be used to separate magnetic from non-magnetic materials.

TABLE 1.3.7

Rules for mixtures

1	Mixtures can be separated by physical methods.
2	Mixtures only have the properties of the things in the mixture.
3	Mixtures of elements can be made using different amounts of each one.
4	No chemical change occurs when making mixtures.

3. Would all of a mixture containing iron filings and lead powder be magnetic?
4. If nickel chloride were mixed with lead, could you use a magnet to separate them? Explain your answer.
5. Use the rules in Table 1.3.7 to explain why mixtures can be separated using known differences between the substances.

Separation by filtration

In the laboratory, filter paper can be used to separate solids from liquids – this process is called **filtration**. Substances that do not dissolve are described as **insoluble**. Filtration helps to separate soluble and insoluble solid substances.

Liquids like oil and water do not mix. The oil does not dissolve in the water to make a solution. These liquids are described as **immiscible**. The lighter oil floats on top of the water, and even if you shake the mixture, the two layers will reappear as the two liquids separate again.

The way these two liquids behave means that a separating funnel can be used to split them up. The water layer can be removed using the tap at the bottom, leaving the oil layer behind.

6. Choose a method to separate flour and rice.
7. Explain why a bottle of salad dressing made from vinegar and olive oil must be shaken before use.
8. Explain why filtration would not separate sugar and water.
9. Create a key or flow diagram to help explain which method of separation to use for a mixture.

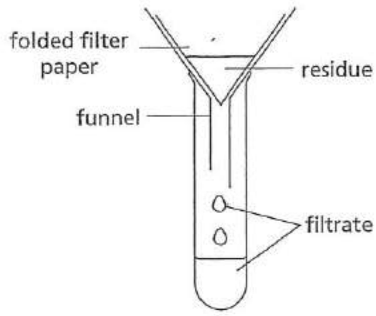


FIGURE 1.3.7c: Separating mixtures by filtration

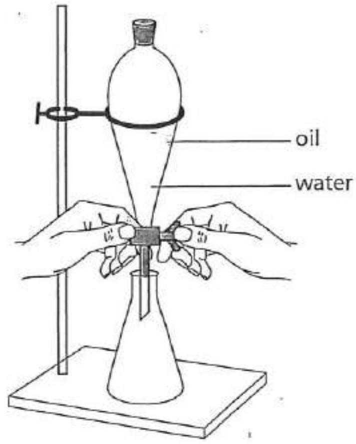


FIGURE 1.3.7d: Using a separating funnel to separate immiscible liquids

Did you know…?

The components of blood can be separated by spinning the blood really fast in a centrifuge. This causes the red blood cells to separate from the plasma because they are denser and sink to the bottom.

Key vocabulary

filter

mixture

filtration

insoluble

immiscible

Chemistry

Dissolving and evaporating

We are learning how to:

- Separate a soluble substance from water.
- Form crystals from solutions.
- Explain solubility.

Gemstones, such as amethyst, are crystal that formed deep in the Earth's crust. Water dissolved salts and as this solution cooled over thousands of years, the precious crystals formed.

FIGURE 1.3.8a: Amethyst crystals formed naturally by the processes of dissolving and evaporating.

Temperature effects

One way to help things dissolve is to increase the temperature of the water. This is why we wash clothes in warm water. Any **soluble** stains in the clothes will dissolve better at a higher temperature. The mass of solute that dissolves in a solvent at a particular temperature is called its **solubility**.

Look at the data in Table 1.3.8. The results show the mass of sugar (sucrose) that can dissolve in 100 cm^3 of water.

TABLE 1.3.8: Dissolving sugar in water at different temperatures

Temperature of water (°C)	0	20	40	80
Mass of sucrose that can dissolve (g)	180	200	240	600

1. What does the data in Table 1.3.8 tell you about the solubility of sucrose at different temperatures?
2. How could you display this data to show the pattern more clearly?
3. Estimate the mass of sucrose that will dissolve at 60 °C.

Did you know…?

These amazing natural gypsum crystals were found 300 metres underground in a mine in Mexico in 2000. They have grown undisturbed for thousands of years. Some are as long as 12 metres.

FIGURE 1.3.8b Naica gypsum crystals

Growing crystals

Heat can also be used to separate soluble substances from their solutions. When the solvent evaporates it leaves behind the solid solute – this is called **crystallisation**. If this process happens quickly, small **crystals** of the solute will form. However, if the evaporation happens slowly, bigger crystals can grow.

Crystallisation happens most efficiently when the solution is **saturated**. This means that there is as much solute dissolved in a solvent as possible. If any more solute is added to a saturated solution it will not dissolve. As the solvent cools, the crystals start to form. The solubility of substances depends on the temperature of the solvent.

4. What is a 'saturated' solution?
5. Describe how you could grow salt crystals.
6. Why do you think that the crystals start to form as the solvent cools?

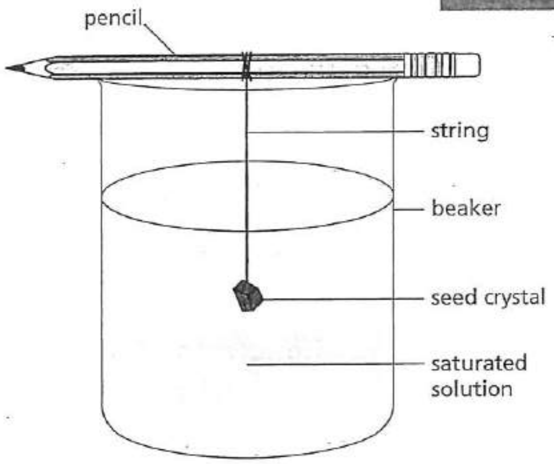


FIGURE 1.3.8c: You can grow your own crystals.

Using graphs

Substances dissolve more in hot water because the water molecules have more energy and move faster. They can break down the crystals and separate the solute molecules more quickly. Solubility also depends on the type of solute. The graph shows the change in solubility of different salts with temperature.

7. Look at Figure 1.3.8d. Which salt is most soluble at 60 °C?
8. If 50 g of potassium nitrate were added to water at 20 °C, would it all dissolve? How do you know?
9. What would you see if a solution containing 50 g of sodium chloride was cooled from 100 °C to 40 °C?
10. How much sodium nitrate would you need to add to 100 g of water at 50 °C to make a saturated solution?
11. Using your knowledge of dissolving, explain why there is a connection between the temperature of a solvent and the solubility of a salt.

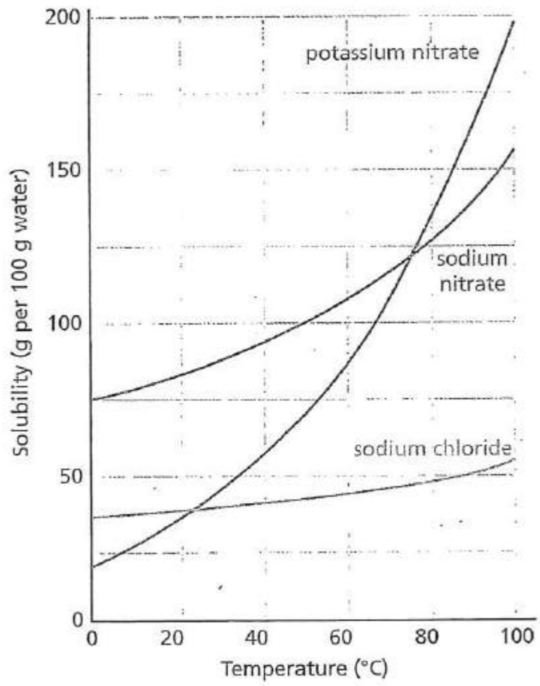


FIGURE 1.3.8d: Solubility graph

Key vocabulary

soluble

solubility

crystallisation

crystal

saturated

Extracting salt

We are learning how to:

- Identify sources of salt and describe how it is extracted.
- Recognise the uses and importance of salt.
- Obtain pure salt from a mixture.

Salt has always been valuable to flavour and preserve food. The chemical name for salt is sodium chloride. We can make chlorine from salt. Chlorine is used to make drinking water safe by killing harmful bacteria.

FIGURE 1.3.9a: Salt crystals

Sea salt

People have obtained **salt** from seawater and salt lakes for thousands of years. The Romans in Britain trapped seawater in shallow ponds. As the water **evaporated**, salt (**sodium chloride**) crystals were left behind. This method is still used in some countries, such as Australia and India. If the seawater is taken from an area that is not polluted, the crystals of sea salt are pure enough to use in cooking.

1. Give two uses for salt.
2. Name one chemical that is made from salt and explain how it is used.
3. How did the Romans obtain salt in Britain?
4. Why do you think the evaporation method of extracting salt is still used in Australia but not in Britain?

FIGURE 1.3.9b: India is the world's third largest salt producer, after China and the USA.

Rock salt

In winter you often see lorries spreading salt and grit on the roads. The salt makes the ice melt and the roads are made safer. This kind of **salt** is called **rock salt**. The rock salt is mined from the ground and broken into a powder, which makes it easier to spread on icy roads.

Rock salt is not pure salt. It is a natural mixture of salt and insoluble materials like clay. Most rock salt is brown, but it can be yellow or red depending on the clay it is mixed with.

You can purify rock salt yourself. Because the salt is soluble but the sand is not, water can be used to help separate the substances. The insoluble materials can be filtered off using a funnel and filter paper, and the remaining solution evaporated to obtain the salt.

5. Give two reasons why rock salt and grit are used on icy roads and pavements.
6. What gives rock salt its colour?
7. What is meant by an 'insoluble material'?
8. Describe how you would separate pure salt from rock salt.

Mining salt

In Cheshire, people have obtained salt from **brine** pits since the 17th century. Brine is salty water. Because salt is soluble in water but rocks are not, water is used to mine the salt. This is called solution mining.

Water is pumped down one of the pipes to dissolve some of the salt underground. The brine is then pumped up and water is evaporated to leave pure, white salt crystals. However, removing the salt from under the ground leaves large holes. The land above can sink into these holes, destroying buildings.

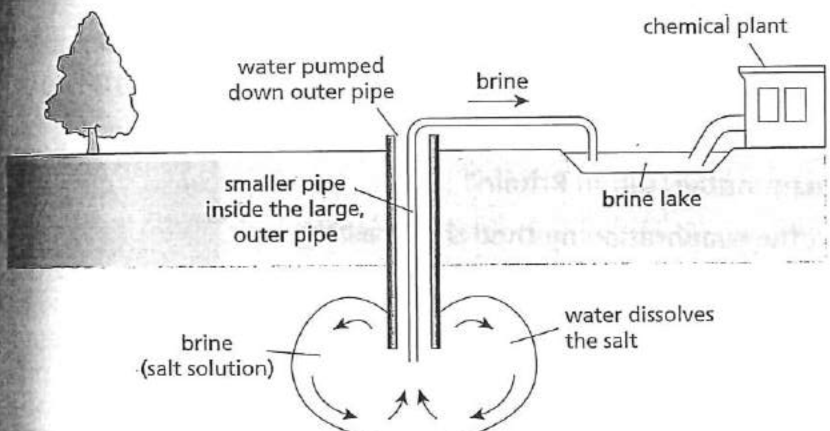


FIGURE 1.3.9c: Using solution mining to extract salt

9. What are the differences between rock salt and the salt extracted by solution mining?
10. Explain, in as much detail as you can, why solution mining is a better source of salt for cooking than rock salt.
11. What are the advantages and disadvantages of solution mining?

Did you know…?

The concentration of salt in the Dead Sea, between Jordan and Israel, is so high that you can float very easily on the water surface. However, only specially adapted microorganisms can survive in it.

Key vocabulary

salt

evaporate

sodium chloride

rock salt

brine

Understanding distillation

We are learning how to:

- Use distillation to separate substances.
- Explain why distillation can purify substances.

Distillation is used in making perfumes, fuels (such as petrol) and alcoholic drinks (such as vodka). It is an important separation process involving heating and cooling.

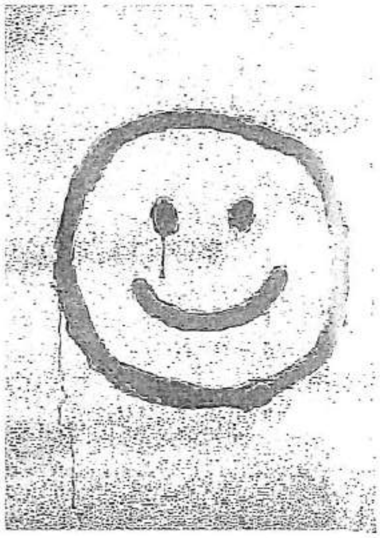


FIGURE 1.3.10a: Condensation is one of the processes involved in distillation.

Heating and cooling

On a cold day water **vapour** from a bath or kettle can **condense** on a cold surface. It cools down and turns back to water. This is what happens in **distillation**. Liquid mixtures can be separated using distillation.

1. Name three substances that are made using distillation.
2. Why does steam turn into liquid water when it touches a window?

Catching steam

When water boils it is hard to catch all of the water vapour because it mixes into the air. In distillation the vapour is cooled, which allows it to be collected as a liquid.

2000 years ago Greek scientists, known as alchemists, invented a way to distil liquids. A copper 'still' trapped the hot vapour, cooling it and condensing it back to a liquid. It was so successful that the design was on sale until 1860.

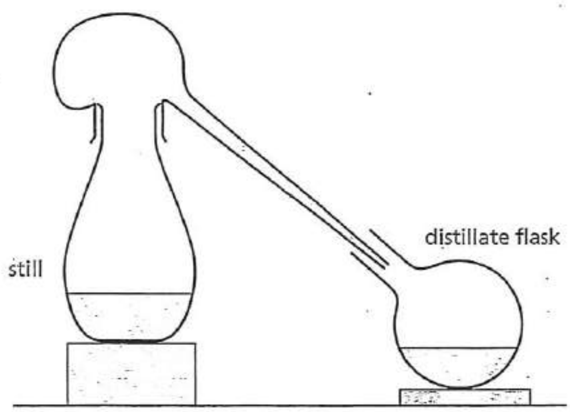


FIGURE 1.3.10b: An early distillation method

The distillation apparatus that we use today is based on the same principle of heating and cooling. The major improvement is the **Liebig condenser**, which is a double glass tube, shown in the apparatus in Figure 1.3.10c. The hot vapour from the boiling liquid flows through the inner tube, while cold water runs though the outer tube. This keeps the inner glass tube cold and condenses most vapours easily. The liquid collected at the end is called the distillate.

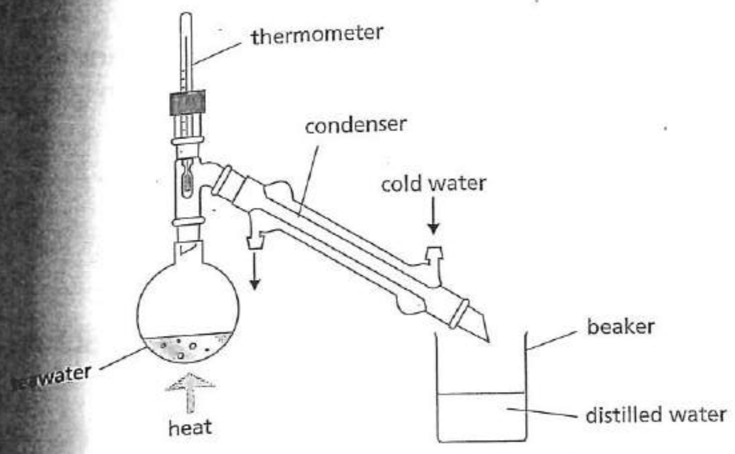


FIGURE 1.3.10c: Distillation apparatus using a Liebig condenser

3. Why is the alchemists' method a better method of separation than just heating a mixture of liquids?
4. Why is the Liebig condenser better than the alchemists' equipment?
5. Explain the safety checks you would use to separate a mixture safely.

Distilling mixtures

There are two changes of state in distillation. First, a liquid is evaporated by heating and then the cooled vapour condensed back to a liquid. When salty water is heated, only the water (solvent) changes state and the salt (solute) is left behind. The water produced is called distilled water.

Different liquids boil at different temperatures – for example, ethanol boils at 78 °C and water at 100 °C. This means that mixtures of liquids can be separated using distillation. A thermometer at the top of a distillation flask shows the temperature of the vapour being condensed and hence identifies the substance being separated. Distillation is an effective way of **purifying** alcohol or increasing the concentration of alcoholic drinks. It is also useful for separating flammable liquids like petrol and diesel because the vapours never come into direct contact with the flame.

6. Why is distillation a better way to separate salt and water than crystallisation?
7. Why is a thermometer important in distillation?
8. Why is distillation a good method for separating petrol and diesel?
9. Explain how water and ethanol are separated.

Did you know...?

Steam distillation is used to obtain essential oils from plants such as herbs and flowers. The products are used in aromatherapy, flavourings in foods and drinks, and as scents in perfumes, cosmetics and cleaning products.

Key vocabulary

vapour

condense

distillation

Liebig condenser

purify

Applying key ideas

You have now met a number of important ideas in this chapter. This activity gives an opportunity for you to apply them, just as scientists do. Read the text first, then have a go at the tasks. The first few are fairly easy – then they get a bit more challenging.

How hard is your water?

Some people have hard water coming out of their taps. It does not really do them any harm, but it can cause problems. A good way to tell if the water is hard in the area where you live is to look inside your kettle at home – in a hard-water area you will see limescale there. It looks like a creamy coloured fur but if you touch it the 'fur' is actually quite hard. You can also tell if you go to wash your hands – the soap will not form much lather in the water, but will tend to form a scum instead.

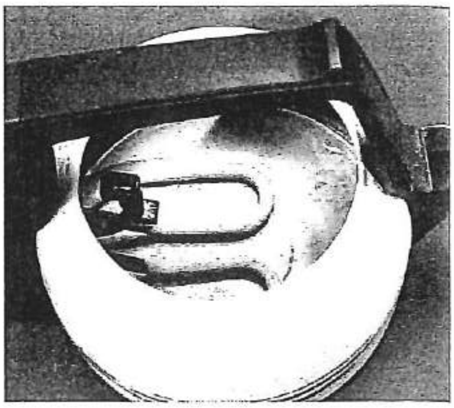


FIGURE 1.3.11a: Limescale in a kettle

Water is hard if it has minerals dissolved in it that contain calcium or magnesium. Some dissolved chemicals cause the hardness to be temporary. These chemicals can be removed by boiling and the water becomes soft. Calcium bicarbonate or magnesium bicarbonate cause temporary hardness. However, if there is calcium sulfate or magnesium sulfate in the water the hardness is permanent – boiling the water will not remove it.

As well as forming deposits on the inside of kettles, the chemicals in hard water can also cause harm to central heating systems, dishwashers and washing machines by clogging them up.

Now, you might wonder how these chemicals get into the water. After all, water falls as rain and rain is considered to be soft – it contains few chemicals. Actually, rain water is slightly acidic (this is natural and, unlike the acid rain caused by pollution, not a problem). The way that water becomes hard is by running over chalk or limestone. Limestone, for example, contains calcium carbonate and the rainwater reacts with this.

Not everybody has hard water though, and in a number of areas it is soft, depending on where the water comes from. The water in Birmingham, for example, comes from reservoirs in the Elan Valley in Wales, which is a soft-water area. Soft water lathers with soap quite easily and does not cause deposits. However, it is not all good news for people in soft-water areas – some people prefer the taste of hard water.

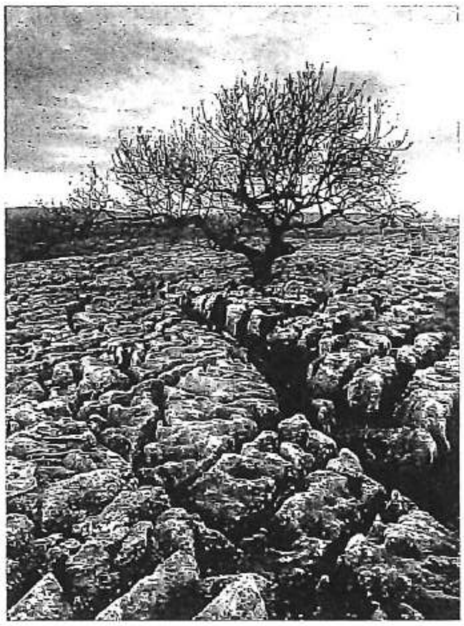


FIGURE 1.3.11b: A limestone landscape

a go at

Task 1: Is your water hard?

Is the water in your area hard? How do you know? People can often taste the difference between hard water and soft water. How can water taste different?

Task 2: Temporary or permanent?

What sort of problems does hard water cause? How does water become hard? What is the difference between temporary hard water and permanent hard water? What causes that difference?

Task 3: Soluble or insoluble?

Limescale is calcium carbonate. Is it soluble or insoluble? How do you know? How could you demonstrate this? What about calcium bicarbonate?

Task 4: Calcium carbonate

Calcium carbonate is made up from the elements calcium, carbon and oxygen and is written as the chemical 'formula' $CaCO_3$. Which symbols represent each element? How can you tell from this formula that each molecule consists of five atoms?

Task 5: Calcium hydrogen carbonate

Calcium bicarbonate has the formula $Ca(HCO_3)_2$. Which elements does it contain? Why do you think it is called calcium *bi*carbonate? Its modern name is calcium hydrogen carbonate. Why is this more useful?

Finding out what air is made of

We are learning how to:

- Describe the composition of air.
- Separate gases from air.

Your body is very effective at separating things out from air. Air is a mixture of gases and small particles of dust, pollen and pollutants. Hairs and mucus in your nose help in removing dust and pollen.

FIGURE 1.3.12a: Particles in the air can affect our health.

Up in the air

Two **gases** make up 98 per cent of the air – nitrogen (N_2) and oxygen (O_2) are diatomic. Nitrogen is not a very reactive gas – however, oxygen is needed to burn fuels for heat, to make electricity and for car engines to run. When oxygen reacts with other elements, compounds called oxides are formed. Carbon dioxide (CO_2) is produced when carbon compounds are burned in air. Animals breathe out carbon dioxide.

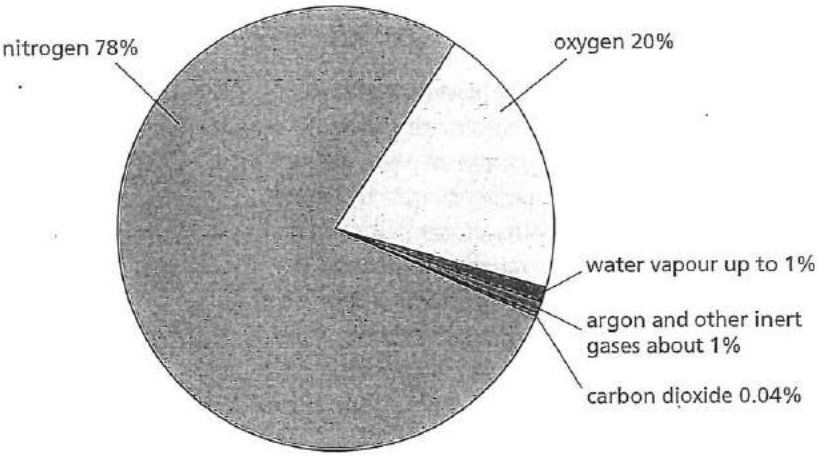


FIGURE 1.3.12b: Air is a mixture.

1. Which are the two most common gases in the air?
2. What name is given to any compound formed from a reaction involving oxygen?
3. Give two ways that carbon dioxide can be released into the air.

Air pollution

The particles and gases produced by burning fuels are released into the air. The pollution this causes has short- and long-term health effects. The daily air quality index (DAQI) tells us how much pollution there is in the air and DEFRA, the government body that produces it, provides health advice. This information is vital, for example, for people with lung problems or asthma.

The **air pollution** information is based on hourly results taken from over 120 automatic monitoring systems across the UK. They detect fine particles and gases such as sulfur dioxide and nitrogen oxides that can irritate our lungs.

1	2	3	4	5	6	7	8	9	10
Low			Moderate			High			Very high

FIGURE 1.3.12c: Daily air quality information is displayed using this scale. (DEFRA)

4. Why is the DAQI information important for children with asthma?
5. Why are so many automated monitoring stations in the UK taking readings every hour?
6. Which pollutants are measured and where do they come from?

Boiling cold?

Most gases have **boiling points** significantly lower than 0 °C. Therefore to separate oxygen from the other gases in air, the distillation process has to take place at very low temperatures. The cryogenic distillation process can produce high-purity gases by pushing the molecules closer. This also means that the gases take up less space. Air is **compressed** and cooled to very low temperatures and the liquid air is allowed to heat up slowly in a fractionating column. Oxygen oils off at –183 °C and the purified gas is stored under pressure.

7. Newborn babies sometimes need to breathe pure oxygen. How is pure oxygen obtained?
8. Why does cryogenic distillation use more energy than normal distillation?
9. Why are gases like oxygen and compressed air stored in pressurised containers?

Did you know…?

'SCUBA' stands for 'self-contained underwater breathing apparatus'. The tanks contain compressed air to allow divers to breathe underwater.

FIGURE 1.3.12d: Scuba divers use tanks of compressed air.

Key vocabulary

gas

air pollution

boiling point

compressed

Exploring chromatography

We are learning how to:

- Use chromatography to separate dyes.

Chromatography is one of the most important separation methods used to identify unknown substances. There are many types of chromatography – some use liquids and some use gases. Chromatography is used by scientists to detect drugs and explosives and to identify dyes and paints.

FIGURE 1.3.13a: Separation by chromatography

Separating colours

Black ink is not just a black colour mixed with water. Black ink is a **mixture** of colours. Filter paper and water can be used to **separate** these colours. This method of separation is called **paper chromatography**. Figure 1.3.13a shows what happens when the colours are separated. Drops of water (solvent) are added to the middle of the paper where the ink spot is placed.

1. What evidence is there that black ink is not pure?
2. What causes the ink to spread across the filter paper?
3. What is chromatography?

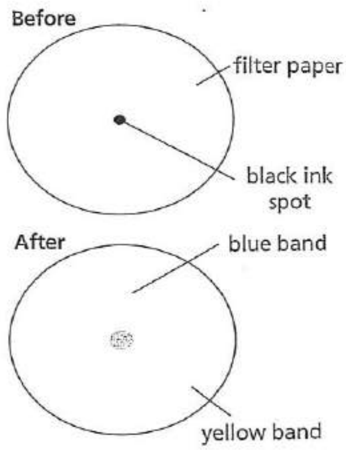


FIGURE 1.3.13b : Separating ink colours

Examples of chromatography

If you cut a section of the filter paper, it can act as a wick. By dipping this wick into water, the liquid is drawn up through the ink and the colour begins to separate all on its own. The resulting pattern of colours is a **chromatogram**.

This method shown in Figure 1.3.13c is called ascending paper chromatography, because the water soaks up from the base carrying the colour spots with it. Some colours move faster than others, which is why the colours separate.

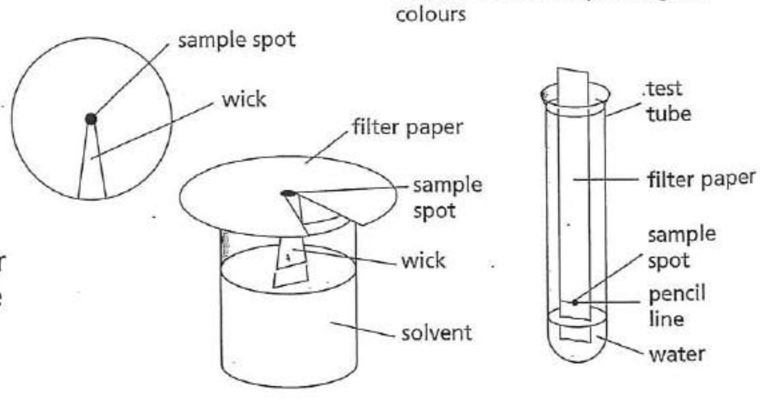


FIGURE 1.3.13c: Other methods of chromatography

You can use chromatography for colourless mixtures, but you must develop the chromatogram by spraying the paper with a chemical to make the spots visible, or using an ultraviolet (UV) light to look at the spots.

4. What do we call the pattern of spots on the paper?
5. Why is the line drawn in pencil and not in ink?
6. Why would paper chromatography be no good for separating salt from water?

Making comparisons

If the same conditions are used, the distance that a coloured dye travels up the paper is always the same. This is how chromatography can be used to identify unknown substances. The distance that the dye travels from the original spot on the pencil line at the base, compared to the distance travelled by the solvent (solvent front) can be calculated. This is called the R_f or retardation factor.

R_f = distance travelled by dye ÷ distance travelled by solvent

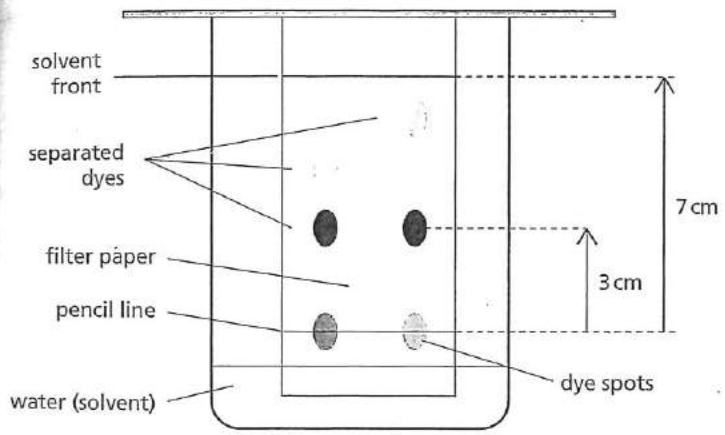


FIGURE 1.3.13e: Chromatogram to compare two dyes

7. Why is the starting line above the water level in the beaker?
8. If two brands of blue dye gave identical spot patterns, what could you conclude?
9. What conclusions can you draw from the chromatogram in Figure 1.3.13e?
10. Some dyes are invisible in normal light and only show up in ultraviolet light. This is how security inks work. How could you use chromatography with a set of security inks?

Did you know…?

You can separate pigments in leaves by chromatography using alcohol as the solvent. Chlorophylls are green pigments that help plants make food via photosynthesis. The yellow pigment separated here is carotene, which is found in carrots and is used as a food colouring (E160a).

FIGURE 1.3.13d: A plant pigment chromatogram

Key vocabulary

mixture

separate

paper chromatography

chromatogram

dye

Using chromatography

We are learning how to:

- Use chromatography to identify unknown substances.
- Draw conclusions from evidence.

Solving crimes requires scientists to produce high-quality evidence that the court will believe and use to prove guilt or innocence. This means that forensic scientists have to be very careful and repeat their experiments to be sure that their evidence is reliable and accurate.

Major crime solved

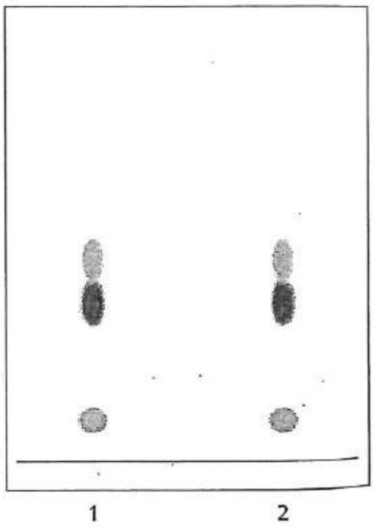
A series of burglaries and break-ins at jewellery stores has netted a gang of criminals thousands of pounds. Unfortunately for them they were careless. Fast driving caused accidents that left traces of car paint at several of the crime scenes. One of the robbers left graffiti messages scrawled on the wall, taunting the police to catch them.

The police **forensic** team used the **reliable** technique of **chromatography** to prove that they had arrested the right gang. The paint left at the crime scenes matched that on the criminals' car perfectly.

Chromatograms of the ink from the wall also exactly matched a set of marker pens found in the gang leader's home and provided the **accurate evidence** needed.

1. What did the forensic scientists deduce after making the chromatogram (Figure 1.3.14b) of the car paint found at the scene?
2. How could they make their conclusion more reliable?
3. Is it sufficient evidence to find that the paint on a car matches that at the scene of the crime?

FIGURE 1.3.14a: The recovered car provided clues.



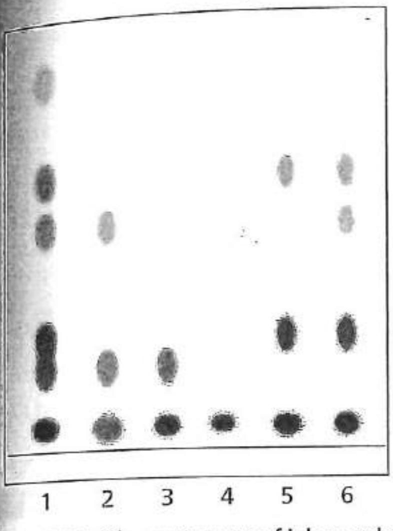
1 Crime scene paint
2 Suspect car paint

FIGURE 1.3.14b: Chromatogram of paint samples

Considering the evidence

Figure 1.3.14c shows a chromatogram using ink from the graffiti messages and ink from four of the pens in a set found in the suspect's home. Consider the evidence from Figure 1.3.14c and answer the following questions.

4. What evidence is there that the graffiti ink was a mixture?
5. How does the evidence from the chromatography prove that the graffiti was drawn by the suspect?
6. Explain how the forensics team could make sure that their evidence was reliable and accurate.



Analysis of ink
1. Crime scene graffiti
2. Suspect pen ink 1a
3. Suspect pen ink 1b
4. Suspect pen ink 2a
5. Suspect pen ink 2b

FIGURE 1.3.14c: Chromatogram of ink samples

Special separation

Samples of DNA gathered at crime scenes can be used to identify and eliminate suspects. The sample is treated with special chemicals and then injected into a gel. When an electric current passes through the gel, the components of the DNA separate and spread, just like the ink on the chromatography paper. This is called electrophoresis. The pattern that the DNA produces is unique to an individual person, like a fingerprint.

Scientists can use DNA 'fingerprints' to find out who you are related to. Your DNA fingerprint contains aspects of the DNA patterns of each of your parents.

7. Explain how DNA fingerprinting is similar to chromatography.
8. What are the differences between chromatography and electrophoresis?
9. What precautions would forensic scientists have to take when gathering and testing DNA evidence?

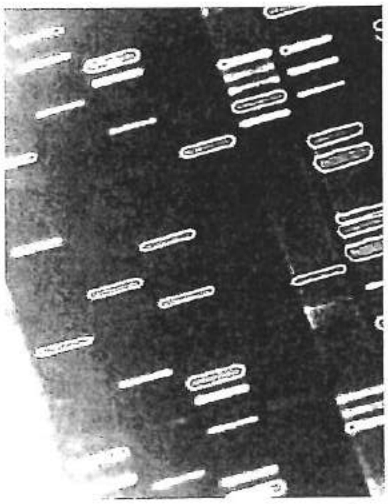


FIGURE 1.3.14d: DNA fingerprinting can help to rule suspects in or out.

Did you know…?

'Chroma' is the Greek word for colour.

Key vocabulary

forensic
reliable
chromatography
accurate
evidence

Finding the best solvent

We are learning how to:

- Choose the best solvent.
- Recognise hazards when using solvents.

Most graffiti artists use spray paints that cannot be washed away with water. To remove spray paint, a different solvent is needed to dissolve the paint.

FIGURE 1.3.15a: Some graffiti has become famous.

Solvent choice

There are many materials like spray paint and oil that are **insoluble** in water, so we need other **solvents** to **dissolve** them. For example, petrol is a very good solvent for oily stains and spray paint, but it is too dangerous to use because it is very flammable. Scientists use **hazard** symbols to highlight the risks of chemicals like solvents, see Table 1.3.15.

FIGURE 1.3.15b: You can buy special stain removers.

1. Why can we not simply wash away graffiti with water?

2. Which solvent would you choose to remove:

  a) nail polish from glass?

  b) ballpoint pen mark from a shirt?

  c) emulsion paint from paint brushes?

3. What hazards are involved when using solvents other than water?

TABLE 1.3.15: Properties of solvents

Solvent	It can dissolve	Hazards
water	sugar, food colours, emulsion paint	none
alcohol (ethanol)	ballpoint pen ink, perfume, herbs, spices	
acetone (propanone)	nail polish	
white spirit	grease, oil paint	

Careful choice

Tar stuck to the paint of a car is insoluble in water and difficult to remove. If you try to clean it off with solvents like acetone or white spirit, they will not only remove the tar, but also the paint on the car.

The choice of solvent is very important and must be selected by careful testing and checking. This is important for clothing too. If you use the wrong solvent you could damage the dyes and fabric.

4. What are the advantages and disadvantages of using tar and stone chippings on road surfaces?
5. Why might there be a problem in removing tar from a car?
6. Explain why there is a need to buy different stain removers when removing stains from clothing.

Did you know ...?

Metals can dissolve in each other to form alloys. Dentists used to use mercury alloys for fillings in teeth. Now most fillings are made from ceramics that avoid the possible harmful effects of metal alloys in your mouth.

Clean and smelly

Dry cleaning uses a solvent called tetrachloroethene (C_2Cl_4) instead of water. The clothes are washed in the solvent at 30 °C before being tumbled in warm air (60 °C) to remove it. All the vapours produced are cooled and the condensed solvent is collected. Dry cleaners can recycle nearly 100 per cent of the solvent. This is important because the solvent is classified as highly toxic as well as harmful to the environment.

Alcohols like ethanol can dissolve colours, flavours and odours to make scented products like perfume. Alcohol evaporates easily, which is why perfume or aftershave dries so quickly on your skin. Liquids that evaporate quickly are described as **volatile**. This property allows us to smell substances, but it can also make solvents more dangerous. This is because the substances are more flammable and can enter the lungs quickly when they are vapours.

FIGURE 1.3.15c: Perfume evaporates easily.

7. How is the dry-cleaning solvent recycled?
8. Why is it important that dry cleaners recycle as much solvent as possible?
9. What are the advantages and disadvantages of using a volatile solvent?

Key vocabulary

insoluble

solvent

dissolve

hazard

volatile

Modelling mixtures and separation

We are learning how to:

- Explain what happens to mass during dissolving.
- Use a circle model to explain dissolving and separation.

Architects use drawings and models to show how new buildings might look. These models are smaller, simpler copies of the real thing. Similarly, we can use a scientific **model** to help explain observations in science.

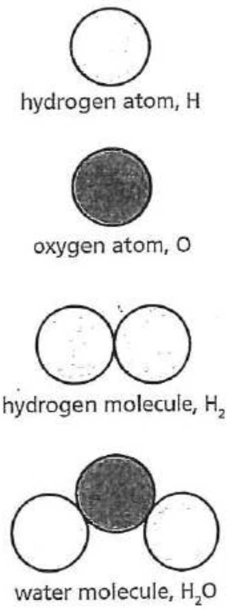


FIGURE 1.3.16a: Atoms and molecules represented by the circle model

Circle models of substances

A circle model helps us to understand the composition of substances. Each circle represents an **atom**. Different colours represent different atoms. When atoms bond together they form a **molecule**. If a molecule contains different types of atom it is called a compound. If a substance only contains one type of atom or molecule it is **pure**. Mixtures can contain any number or type of different atoms or molecules.

1. Why are circle models useful?

2. Draw circle models to represent:

a) one atom

b) a molecule consisting of two identical atoms

c) a molecule consisting of two different atoms

d) a mixture of different molecules.

Conservation of mass

When salt dissolves in water the crystals seem to disappear, but they are still there, mixed with the water molecules. This can be proved by measuring the mass of the substances. No atoms are lost and no new atoms are added. This is called the **Law of Conservation of Mass.**

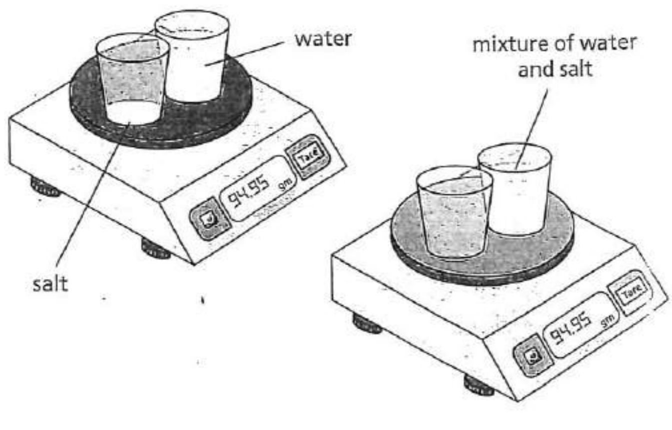


FIGURE 1.3.16b: The mass of water and salt on the first balance is the same as the mass of the mixture on the second balance.

3. What is a solution?
4. How does the mass of a solution show that the solute has not disappeared?
5. Draw diagrams, using the circle model, of a) salt and water, b) salt dissolved in water, to illustrate the Law of Conservation of Mass.
6. The same experiment was repeated, but this time the mass of the solution was lower than the original mass of the salt and water. What might have happened?

Modelling

In Figure 1.3.16c, showing filtration, the filtrate particles are drawn smaller to show that it can pass through the filter paper. Different colours are used to represent the different substances. The filtrate is a mixture of the smaller particles of two substances.

Models simplify a process to help explain how things work. You do not always need to see all the detail to understand what is happening.

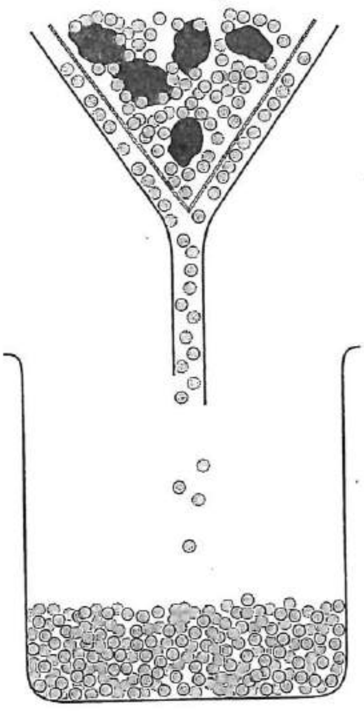


FIGURE 1.3.16c: A model of filtration

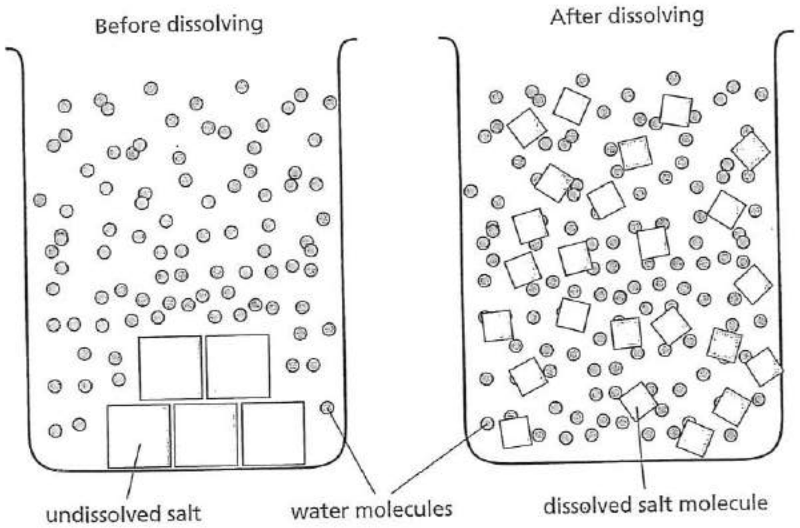


FIGURE 1.3.16d: This model shows dissolving.

7. In what ways is the model shown in Figure 1.3.16d a good one for dissolving?
8. How could this model be improved?
9. Draw a model to show:
   a) evaporation of water from salt solution
   b) separation of iron filings from sand.

Did you know…?

Chocolate is a mixture. The ratio of cocoa, sugar, milk and fat is carefully controlled and blended so that the chocolate melts in your mouth at the right temperature.

Key vocabulary

model

atom

molecule

pure

Law of Conservation of Mass

Checking your progress

To make good progress in understanding science you need to focus on these ideas and skills.

Name and draw equipment and explain obvious laboratory risks.	Select and draw apparatus accurately; explain safety precautions.	Justify equipment choice and measurements; explain how to reduce risks.
Use 2D images to represent a range of laboratory equipment.	Use laboratory equipment safely to gather evidence.	Record evidence in an effective way.
Describe how to separate mixtures.	Select and explain appropriate separation techniques.	Explain the choice and method of separation using correct terms.
Describe the process of dissolving and the effect of temperature.	Describe methods for producing crystals of different sizes.	Use data to draw conclusions about solubility.
Understand that seawater is a mixture.	Explain why most water is not pure, and why this is not necessarily a problem.	Explain why contaminated water is a problem and identify what can be done about it.
Identify sources and uses of salt.	Describe how salt is extracted.	Recognise advantages and disadvantages of salt extraction methods.

Describe the process of distillation.	Explain the physical processes involved in distillation.	Identify the uses and advantages of distillation.
Describe the composition of air.	Identify sources of air pollution and their impact.	Explain how distillation can be used to separate gases in air.
Identify mixtures using chromatography.	Explain how to separate a mixture using chromatography and interpret chromatograms.	Use chromatograms to explain the composition of mixtures; compare chromatography and DNA analysis.
Explain the idea of a solvent.	Explain mass changes during dissolving; select solvents for different uses.	Use a model to explain dissolving and separation; link the uses of solvents to their properties.

Questions

Questions 1–6

See how well you have understood the ideas in the chapter.

1. What is the chemical symbol for copper? [1]

a) Pc **b)** Co **c)** Cp **d)** Cu

2. What do we mean by an insoluble material? [1]

a) It will not dissolve.
b) You cannot get it back after it has dissolved.
c) It dissolves other things well.
d) It will dissolve easily.

3. Which are the two most common gases in the air? [2]

a) helium **b)** nitrogen **c)** carbon dioxide **d)** oxygen

4. Explain two ways in which you could reduce the risks when heating a substance in a test tube. [2]

5. You are trying to get a number of different stains out of your school bag. Give two reasons why you might need to use different stain removers for different stains. [2]

6. Explain how you could safely demonstrate that salt can be recovered from brine (salt water). [4]

Questions 7–12

See how well you can apply the ideas in this chapter to new situations.

7. A good way of separating a mixture of petrol and water is: [1]

a) distillation **b)** filtering **c)** crystallisation **d)** chromatography

8. Jared likes lots of sugar in his coffee. However, one day he forgets to drink it and tips the cold coffee away. He notices that the sugar has formed a sludge in the bottom of the mug, which he was surprised about because he knew he'd stirred it all in. What is the most likely explanation? [1]

a) If you leave it, sugar doesn't stay dissolved in a liquid for long.
b) Sugar is insoluble in coffee.
c) The sugar had reacted with the coffee.
d) Not as much sugar could dissolve in the cold coffee as in the hot coffee.

9. A sample of water was heated until it all evaporated and left a thin layer of white crystals behind. This proved that:

a) it was salt water
b) it had something dissolved in it
c) it was pure water
d) it was not fit to drink

10. Sally is trying to purify muddy water by filtering it. Which of these statements is *not* true? [1]

a) This will remove bits of silt that are floating in the water.

b) It will remove things that have dissolved in it.

c) The water will be clearer after filtering.

d) It will not remove soluble solids.

11. Marcus and Lisa are investigating how well different brands of sugar dissolve in water. Using Table 1.3.18a:

a) Explain what the results show. [2]

b) What do they have to do to make sure it is a fair test? [2]

TABLE 1.3.18a

Brand of sugar	Mass used (g)	Volume water (cm^3)	How many stirs to dissolve it all
Acme	10	100	14
Bonzo	10	100	8
Carefree	20	200	12
Delightful	20	200	7

12. Maisie has three different makes of black felt-tip pen and wonders if the manufacturers made their inks in the same way. Describe an experiment she could conduct to see if the three makes of ink all contain the same colours. [4]

Questions 13–14

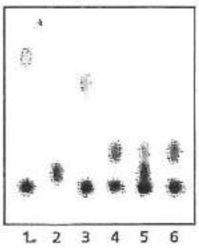
See how well you can understand and explain new ideas and evidence.

13. James is conducting an investigation into how well a sweetener dissolves. What does the data in Table 1.3.18b tell you about the solubility of the sweetener at different temperatures? [2]

TABLE 1.3.18b

Temperature of water (°C)	20	30	40	50
Mass of sweetener that can dissolve (g)	120	135	155	180

14. A vet has been asked to find out if any of four horses, A, B, C and D, have been drugged. She takes urine samples from the four horses and arranges for a lab to prepare a chromatogram to test the samples. What do the results show? [4]



Analysis of urine samples

1. Drug X
2. Drug Y
3. Horse sample A
4. Horse sample B
5. Horse sample C
6. Horse sample D

FIGURE 1.3.18: Chromatogram of horse urine samples

Science
Year 11

Contents

B 10 The human nervous system

10.1 Principles of homeostasis

Learning objectives

After this topic, you should know:

- why it is important to control your internal environment
- the key elements of control systems.

Synoptic links

You learnt about the effect of temperature and pH changes on enzyme activity in Topic B3.5.

Synoptic links

You will learn more about the role of the hormonal system in Chapter B11.

Go further

Scientists are investigating homeostasis in organisms from whales to plants. More and more astonishing mechanisms are being discovered. They range from colour changes to regulate body temperature in invertebrates, to protecting the immune system from responding at the wrong time in plants.

Human beings live everywhere from the equator to the Antarctic. People survive wearing no clothes or many clothes, running a marathon, or never moving from the computer screen. Conditions can change dramatically around us and even inside us and yet we survive. How do we do it?

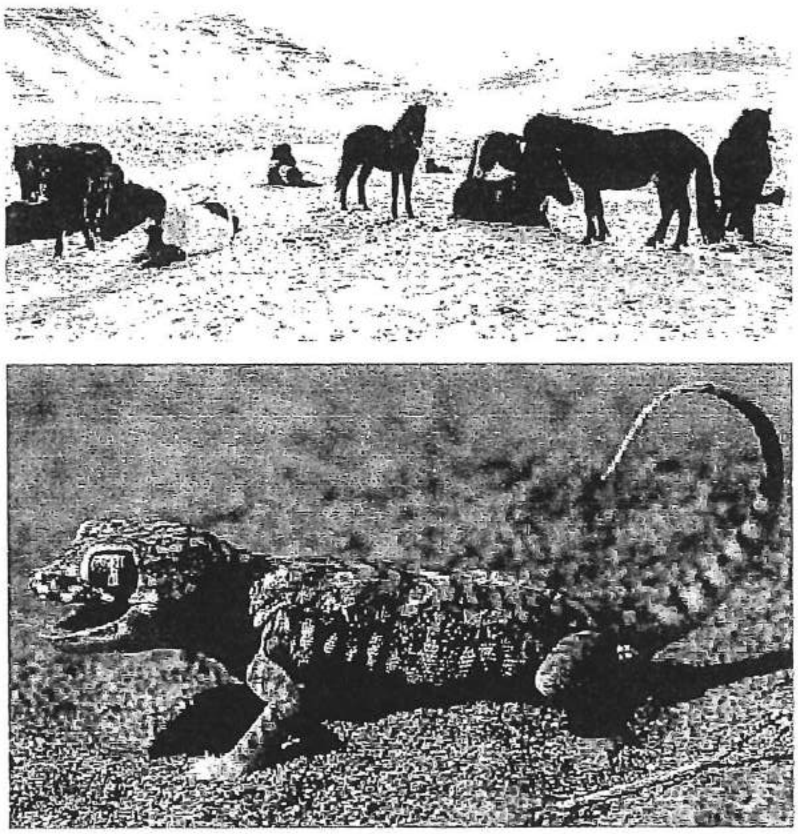


Figure 1 *Human beings are not the only organisms who can survive in extremes of temperatures. Animals and plants all have complex coordination and control mechanisms that enable them to cope with dramatic changes in the external environment*

Homeostasis in action

The conditions inside your body are known as its internal environment. Your organs cannot work properly if this keeps changing. Many of the processes that go on inside your body aim to keep everything as constant as possible. As well as the body as a whole, this includes the regulation of the internal conditions of cells to maintain optimum conditions for functioning, in response to internal and external changes. This balancing act is called **homeostasis**.

You know that enzymes only work at their best in specific conditions of temperature and pH. Enzymes control all the functions of a cell. The functioning of individual cells is vital for the way tissues, organs, and whole organisms work. It is important to respond to changes in the internal or external environment to maintain optimum conditions for the cellular enzymes.

Internal conditions that are controlled include:

- body temperature
- the water content of the body
- blood glucose concentration.

Working together

Homeostasis involves coordination and control. Organisms need to be aware of changes in the world around them, such as changes in temperature or levels of sunlight. They also need to respond to changes in the internal environment. When you exercise your muscles get hotter, when you have eaten a meal your blood sugar levels go up, and in hot weather you lose water and salt through sweating.

Detecting changes and responding to them involves automatic control systems. These automatic systems include nervous responses in your nervous system and chemical responses in your hormone system. They also involve many of your body organs.

Figure 2 *During the month of Ramadan, Muslims fast from dawn to sunset. Homeostatic mechanisms maintain the blood sugar levels and the ion and water balance of the body during the hours of fasting*

The demands of a control system

All control systems in the body need certain key features to function:

- **Receptors**: cells that detect changes in the internal or external environment. These changes are known as **stimuli**. Receptors may be part of the nervous or the hormonal control systems of the body.
- **Coordination centres**: areas that receive and process the information from the receptors. They send out signals and coordinate the response of the body. They include the brain, which acts as a coordination centre for both the nervous system and parts of the hormonal system, the spinal cord, and some organs such as the pancreas.
- **Effectors**: muscles or glands that bring about responses to the stimulus that has been received. These responses restore conditions in the body to the optimum levels.

1 Describe homeostasis. [3 marks]

2 Compare receptors, coordination centres, and effectors. [6 marks]

3 **a** Describe three ways in which your external environment might vary. [3 marks]

b Explain how each of your answers to part a affects your body. [6 marks]

Key points

- Homeostasis is the regulation of the internal conditions of a cell or organism to maintain optimum conditions for function, in response to internal and external changes.
- Homeostasis is important for maintaining optimal conditions for enzyme action and all cell functions.
- In the human body homeostasis includes control of blood glucose concentration, body temperature, and water levels.
- The automatic control systems may involve nervous or chemical responses.
- All control systems include receptors, coordination centres, and effectors.

B10.2 The structure and function of the human nervous system

Learning objectives

After this topic, you should know:

- why you need a nervous system
- how the structure of the nervous system is adapted to its function
- how receptors enable you to respond to changes in your surroundings.

Figure 1 *Your body is made up of millions of cells that have to work together. Whatever you do with your body, whether it's walking to school, learning to drive, or playing on the computer, your movements need to be coordinated*

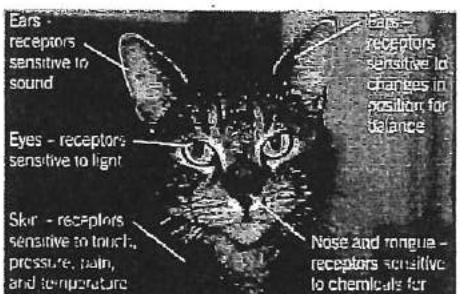


Figure 2 *This cat relies on its sensory receptors to detect changes in the external environment.*

Synoptic link

You learnt about specialised nerve cells in Topic B1.4.

You need to know what is going on in the world around you. Your nervous system makes this possible. It enables you to react to your surroundings and coordinate your behaviour.

Your nervous system carries electrical signals (impulses) that travel fast – between 1 and 120 metres per second. This means you can react to changes in your surroundings very quickly.

The nervous system

As with most animals, you need to avoid danger, find food, and eventually find a mate. This is where your nervous system helps. Your body is particularly sensitive to changes in the world around you. Any changes (known as stimuli) are picked up by cells called receptors.

Receptor cells, such as the light receptor cells in your eyes, are similar to most animal cells. They have a nucleus, cytoplasm, and a cell membrane. These receptors are usually found clustered together in special sense organs, such as your eyes and your skin. You have many different types of sensory receptor. Some male moths have receptors so sensitive they can detect the scent of a female several kilometres away and follow the scent trail to find her.

How your nervous system works

Once a sensory receptor detects a stimulus, the information is sent as an electrical impulse that passes along special cells called **neurones**. These are usually found in bundles of hundreds or even thousands of neurones known as **nerves**.

The impulse travels along the neurone until it reaches the **central nervous system** (CNS). The CNS is made up of the brain and the spinal cord. The cells that carry impulses from your sense organs to your CNS are called **sensory neurones**.

Your brain gets huge amounts of information from all the sensory receptors in your body. It coordinates the response to the information, and sends impulses out along special cells. These cells, called **motor neurones**, carry information from the CNS to the rest of your body. They carry impulses to make the right bits of your body – the **effectors** – respond.

Effectors may be muscles or glands. Your muscles respond to the arrival of impulses by contracting. Your glands respond by releasing (secreting) chemical substances. For example, your salivary glands produce and release extra saliva when you smell food cooking, and your pancreas releases the hormone insulin when your blood sugar levels go up after a meal.

B10.3 Reflex actions

Learning objectives

After this topic, you should know:

- what reflexes are
- how reflexes work
- why reflexes are important in your body.

Your nervous system lets you take in information from your surroundings and respond in the right way. However, some of your responses are so fast that they happen without giving you time to think.

When you touch something hot, or sharp, you pull your hand back before you feel the pain. If something comes near your face, you blink. Automatic responses like these are known as **reflexes**.

What are reflexes for?

Reflexes are very important both for human and other animals. They help you to avoid danger or harm because they happen so fast. There are also lots of reflexes that take care of your basic body functions. These functions include breathing and moving food through your digestive system.

Reflexes are automatic and rapid – they do not involve the conscious part of your brain. It would make life very difficult if you had to think consciously about those things all the time – and it would be fatal if you forgot to breathe!

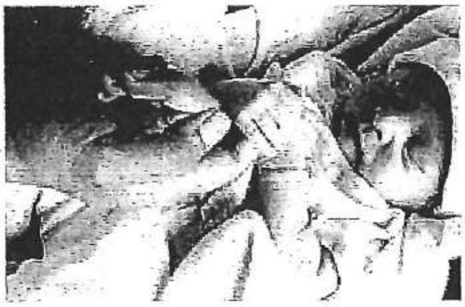


Figure 1 *Newborn babies have a number of special reflexes that disappear as they grow. This grasp reflex is one of them*

How do reflexes work?

Simple reflex actions such as the pain withdrawal reflex we are all familiar with often involve just three types of neurone. These are:

- sensory neurones
- motor neurones
- relay neurones – these connect a sensory neurone and a motor neurone, and are found in the CNS.

An electrical impulse passes from the receptor along the sensory neurone to the CNS. It then passes along a relay neurone (usually in the spinal cord) and straight back along the motor neurone. From there, the impulse arrives at the effector organ. The effector organ will be a muscle or a gland. We call this pathway a **reflex arc**.

The key point in a reflex arc is that the impulse bypasses the conscious areas of your brain. The result is that the time between the stimulus and the reflex action is as short as possible.

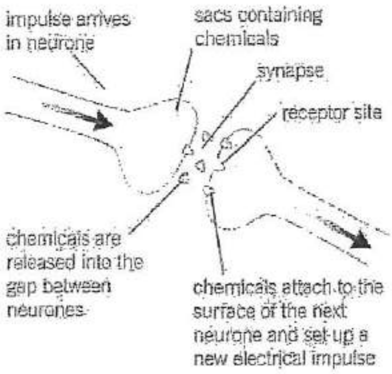


Figure 2 *When an impulse arrives at the junction between two neurones, chemicals are released that cross the synapse and arrive at receptor sites on the next neurone. This starts up a new electrical impulse in the next neurone.*

How do synapses work?

Your neurones are not joined up directly to each other. There are junctions between them called synapses which form physical gaps between the neurones. The electrical impulses travelling along your neurones have to cross these synapses. They cannot leap the gap. The diffusion of the chemical across the synapse is slower than the electrical impulse in the neurones, but it makes it possible for the impulse to cross the gap between them. Figure 2 shows you how this happens.

The way your nervous system works can be summed up as:

$$\text{stimulus} \rightarrow \text{receptor} \rightarrow \begin{matrix}\text{coordinator}\\ \text{(CNS)}\end{matrix} \rightarrow \text{effector}$$

The receptor sends an impulse along a sensory neurone, carrying information about a change in the environment to the coordinator (CNS). Once all the incoming information has been processed, the coordinator sends impulses down motor neurones. These motor impulses stimulate the effectors to bring about the responses needed in any particular situation.

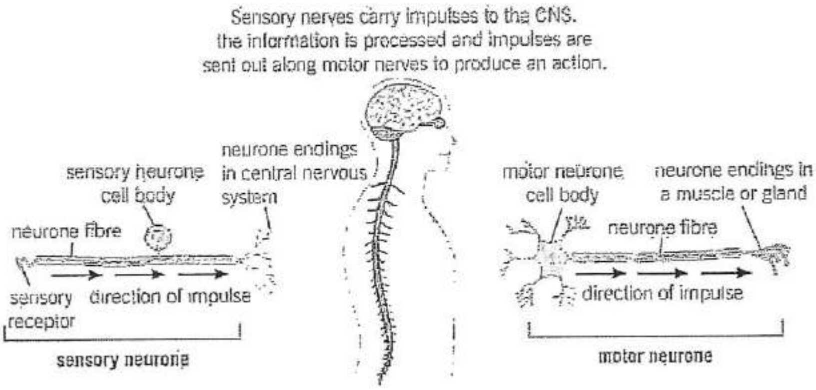


Figure 3 *The rapid responses of our nervous system allow us to respond to our surroundings quickly – and in the right way*

Measuring reaction times

There are many ways to investigate how quickly nerve impulses travel in your body. Two simple methods are:

- use the ruler drop test or digital sensors to measure how quickly you react to a visual stimulus
- stand in a circle holding hands with your eyes closed and measure how long it takes a hand-squeeze to pass around the circle.

People claim that activities such as drinking cola, talking on the phone, and listening to music affect our reaction times. Choose a factor that interests you and use these simple techniques to investigate the effect it has – or does not have – on human reaction times.

Safety: Do not drink or eat in the laboratory.

1 **a** State the main function of the nervous system. [3 marks]
b Describe the difference between a neurone and a nerve. [2 marks]
c Describe the difference between a sensory neurone and a motor neurone. [3 marks]

2 **a** State the different types of sense receptor. [5 marks]
b For each of the above receptors, give one example of what it responds to. [5 marks]

3 Explain what happens in your nervous system when you see a piece of fruit, pick it up, and eat it. [6 marks]

Study tip

Be careful to use the terms neurone and nerve correctly.

Talk about impulses (*not* messages) travelling along a neurone.

Key points

- The nervous system uses electrical impulses to enable you to react quickly to your surroundings and coordinate your behaviour.
- Cells called receptors detect stimuli (changes in the environment).
- Impulses from receptors pass along sensory neurones to the brain or spinal cord (CNS). The brain coordinates the response, and impulses are sent along motor neurones from the brain (CNS) to the effector organs.

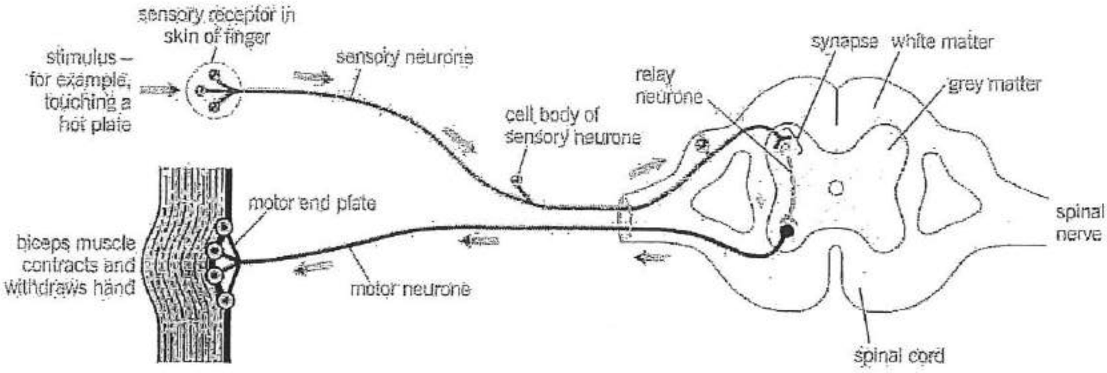


Figure 3 *The reflex action that moves your hand away from something hot can save you from being burned. Reflex actions are quick and automatic – you do not think about them*

The reflex arc in detail

Look at Figure 3. It shows what would happen if you touched a hot object.

- When you touch the object, a receptor in your skin is stimulated. An electrical impulse from a receptor passes along a sensory neurone to the CNS – in this case, the spinal cord.
- When an impulse from the sensory neurone arrives at the synapse with a relay neurone, a chemical is released. The chemical diffuses across the synapse to the relay neurone where it sets off a new electrical impulse that travels along the relay neurone.
- When the impulse reaches the synapse between the relay neurone and a motor neurone returning to the arm, another chemical is released. Again, the chemical diffuses across the synapse and starts a new electrical impulse travelling down the motor neurone to the effector.
- When the impulse reaches the effector organ, it is stimulated to respond. In this example, the impulses arrive in the muscles of the arm, causing them to contract. This action moves the hand rapidly away from the source of pain. If the effector organ is a gland, it will respond by releasing (secreting) chemical substances.

The reflex pathway is not very different from a normal conscious action. However, in a reflex action the coordinator is a relay neurone either in the spinal cord or in the unconscious areas of the brain. The whole reflex is very fast indeed.

An impulse also travels up the spinal cord to the conscious areas of your brain. You know about the reflex action, but only after it has happened.

1 **a** Why are reflexes important? [2 marks]
   b Why is it important that reflexes don't go to the conscious areas of your brain? [1 mark]

2 Explain why some actions such as breathing and swallowing are reflex actions, while others such as speaking and eating are under your conscious control. [4 marks]

3 Describe what happens when you step on a pin. Make sure you indicate when an electrical impulse or a chemical impulse is involved. [6 marks]

Study tip

Learn the reflex pathway off by heart.

stimulus → receptor → sensory neurone → relay neurone → motor neurone → effector → response.

Key points

- Reflex actions are automatic and rapid and do not involve the conscious parts of the brain.
- Reflexes involve sensory, relay and motor neurones.
- Reflex actions control everyday bodily functions, such as breathing and digestion, and help you to avoid danger.
- The main stages of a reflex arc are: **stimulus → receptor → sensory neurone → relay neurone → motor neurone → effector → response**

B10 The human nervous system

Summary questions

1 a What is homeostasis? [3 marks]
b Explain why the control of conditions inside your body is so important. [4 marks]

2 Match up **A–F** with **U–Z** to make complete sentences about animal responses.

A Many processes in the body …	**U** … effector organs.
B The nervous system allows you …	**V** … secreted by glands.
C The cells that are sensitive to light …	**W** … to react to your surroundings and coordinate your behaviour.
D Hormones are chemical substances …	**X** … are found in the eyes.
E Muscles and glands are known as …	**Y** … are known as nerves.
F Bundles of neurones …	**Z** … are controlled by hormones.

[6 marks]

3 a State the job of your nervous system. [2 marks]
b State where in your body you would find nervous receptors that respond to:
i light [1 mark]
ii sound [1 mark]
iii temperature [1 mark]
iv touch. [1 mark]
c Draw and label a simple diagram of a reflex arc. [4 marks]
Explain carefully how a reflex arc works and why it allows you to respond quickly to danger. [4 marks]

4

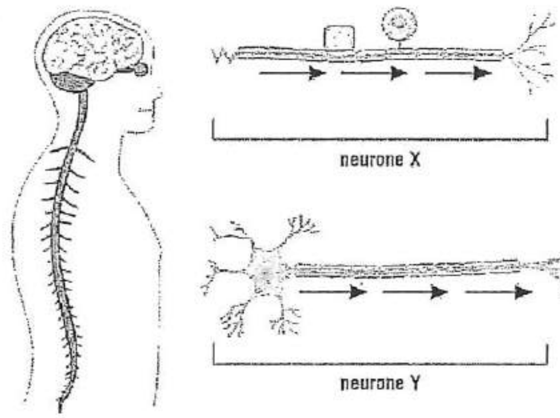


Figure 1

a State the difference between neurone X and neurone Y. [2 marks]
b State the difference between a neurone and a nerve. [3 marks]
c Draw and label a synapse. [3 marks]
d Describe how a nerve impulse passes across a synapse. Explain the importance of synapses in the nervous system. [4 marks]

5 Lots of people drink coffee or caffeinated drinks because they think it keeps them awake or speeds up their reaction times.
In a class investigation to see if caffeine has an effect on simple reaction times, two groups of students had their mass reaction times measured by standing in a ring and squeezing hands. Their responses were measured before and 10 minutes after having a drink. One group was given a caffeinated drink, the other was not.

Table 1

	Mass reaction times (mins)			Mass reaction times (min) 10 minutes after a drink		
Group A	4.0	3.8	3.6	3.8	3.8	3.6
Group B	4.2	4.0	3.8	3.6	3.4	3.2

a Calculate the mean mass reaction times for both groups before having a drink. [2 marks]
b Calculate the mean mass reaction times for both groups 10 minutes after having a drink. [2 marks]
c Which group do you think was given a drink containing caffeine? Explain your answer. [4 marks]
d Suggest a reason why the mass reaction times of both groups fell during the test. [2 marks]

Practice questions

01 A student did an investigation to see if reaction time was affected by the sense organ stimulated.
A computer measured how quickly she clicked the mouse when she:

- saw a shape appear on the screen

or

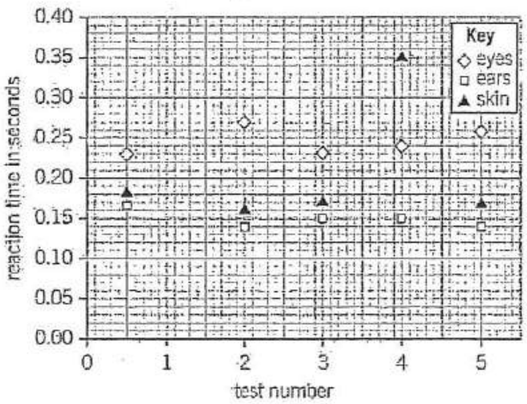
- heard a man shout 'Stop!'

or

- felt a bar vibrate in her hand.

Each sense organ was tested five times.
Figure 1 shows her results.

Figure 1



01.1 The data is shown as a scatter graph rather than a line graph.
Suggest why. [1 mark]

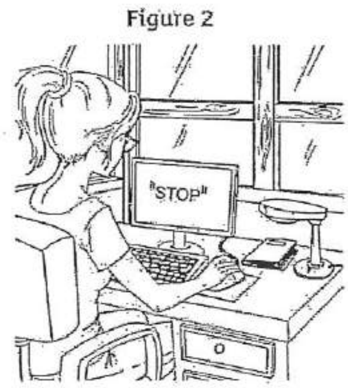
01.2 The results shown in the scatter graph might be easier to understand if they were drawn as a bar chart.
Describe what would have to be done with these results before they could be shown in a bar chart. [2 marks]

01.3 Give **one** conclusion that can be made from these results. [1 mark]

AQA, 2013

02 Some students investigated the effect of caffeine on a person's reaction time.
Figure 2 shows how they measured reaction time using a computer program.

Figure 2



When the woman saw Stop! appear on screen she clicked the mouse.
She did this five times.
She then drank a cup of strong coffee. Coffee contains caffeine.
After drinking the coffee the woman sat for 30 minutes.
The students then tested her reaction time another five times using the same computer program.

02.1 What was the independent variable in this investigation? [1 mark]

02.2 Why did the woman sit for 30 minutes after drinking the coffee, before the students measured her reaction time? [1 mark]

Table 1 shows the results.

Table 1

Test number	Reaction time in seconds	
	Before drinking coffee	After drinking coffee
1	0.343	0.301
2	0.348	0.303
3	0.354	0.303
4	0.352	0.307
5	0.348	0.301
Mean	0.349	

02.3 What would be the best way to display these results?
A bar chart
B histogram
C line graph
D scatter diagram [1 mark]

02.4 Calculate the mean reaction time after drinking coffee. [2 marks]

02.5 What conclusion can be made from these results? [1 mark]

02.6 (H) Suggest **two** improvements the students could make to the investigation to produce more valid results. [2 marks]

03 If you touch a hot object you pull your hand away.
This is an example of a reflex action.

03.1 Describe fully how the different structures of the nervous system bring about this reflex action. [6 marks]

03.2 Explain why reflex actions are important to the body. [2 marks]

B 11 Hormonal coordination

11.1 Principles of hormonal control

Learning objectives

After this topic, you should know:

- what a hormone is
- the main organs of the endocrine system
- the role of the pituitary gland.

Figure 1 *Many aspects of the growth of children from birth to adulthood is controlled by hormones*

Go further

Hormones have their effects on the body by their interaction with DNA and the process of protein synthesis.

In Chapter B 10 you discovered how the nervous system acts to coordinate and control your body, reacting in seconds to changes in your internal and external environments. However, it is very important that your body acts as a coordinated whole, not just from minute to minute but from day to day and year to year throughout your life. You have a second coordination and control system to help with this – the **endocrine system**.

The endocrine system

The endocrine system is made up of glands that secrete chemicals called **hormones** directly into the bloodstream. The blood carries the hormone to its target organ (or organs) where it produces an effect. The target organ has receptors on the cell membranes that pick up the hormone molecules, triggering a response in the cell.

Many processes in your body are coordinated by these hormones. Hormones can act very rapidly but, compared to the nervous system, many hormonal effects are slower but longer lasting. Hormones that give a rapid response include **insulin**, which controls your blood glucose, and **adrenaline**, which prepares your body for fight or flight. Slow-acting hormones with long-term effects include growth hormones and sex hormones.

The endocrine glands

Hormones provide chemical coordination and control for the body and are produced by the endocrine glands. Many endocrine glands around the body are themselves coordinated and controlled by one very small but powerful endocrine gland found in the brain – the **pituitary gland**. The pituitary gland acts as a master gland. It secretes a variety of different hormones into the blood in response to changes in body conditions. Some hormones produced by the pituitary in response to changes in the internal environment have a direct effect on the body. Examples include **ADH**, which affects the amount of urine produced by the kidney, and growth hormone, which controls the rate of growth in children.

Other hormones released by the pituitary affect specific endocrine glands, stimulating them to release hormones that bring about the required effect on the body. These include:

- **follicle stimulating hormone (FSH)**, which stimulates the **ovaries** to make the female sex hormone **oestrogen**, and
- TSH, which stimulates the thyroid gland to make thyroxine, a hormone that helps control the rate of your metabolism.

Each of the endocrine glands produces hormones that have a major effect on the way your body works. The levels of the hormones vary depending on changes in the internal environment of your body. You will learn more about many of these hormones in the next few pages.

Table 1 *The main roles of hormones produced by the different endocrine glands*

Endocrine gland	Role of the hormones
Pituitary	Controls growth in children Stimulates the thyroid gland to make thyroxine to control the rate of metabolism In women – stimulates the ovaries to produce and release eggs and make the female sex hormone oestrogen In men – stimulates the testes to make sperm and the male sex hormone testosterone
Thyroid	Controls the metabolic rate of the body
Pancreas	Controls the levels of glucose in the blood
Adrenal	Prepares the body for stressful situations – 'fight or flight' response
Ovaries	Controls the development of the female secondary sexual characteristics and is involved in the menstrual cycle
Testes	Controls the development of the male secondary sexual characteristics and is involved in the production of sperm

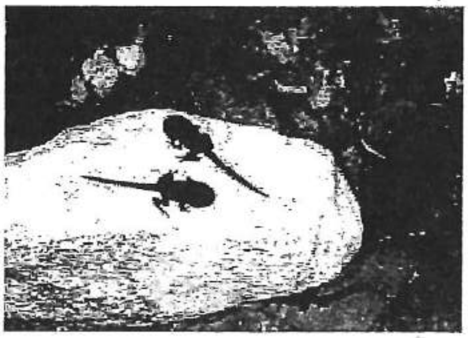


Figure 2 *It isn't just humans who need hormones – without the hormones from their thyroid glands, these tadpoles will never become frogs*

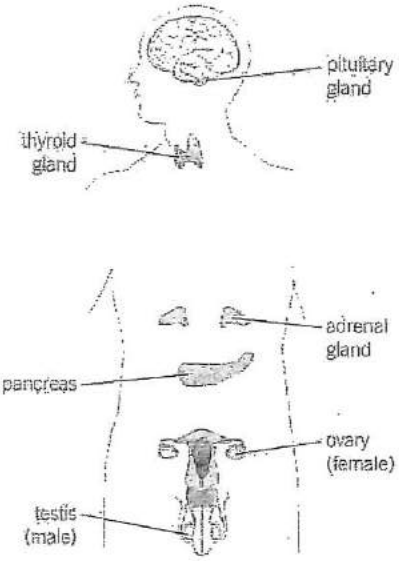


Figure 3 *The main endocrine glands of the human body*

Study tip

Find a way to help you remember the main endocrine organs of the body – for example, learn them in the order they appear in your body from the head downwards.

Key points

- The endocrine system is composed of glands that secrete chemicals called hormones directly into the blood stream. The blood carries the hormone to a target organ where it produces an effect.
- Compared to the nervous system, the effects of hormones are often slower but longer lasting.
- The pituitary gland is the master gland and secretes several hormones into the blood in response to body conditions. Some of these hormones act on other glands and stimulate them to release hormones to bring about specific effects.
- Key endocrine glands are the pituitary, thyroid, pancreas, adrenal glands, ovaries, and testes.

1 **a** What is a hormone? [1 mark]
b What is an endocrine gland? [1 mark]

2 Explain how coordination and control by hormones differs from coordination and control by the nervous system. [6 marks]

3 Suggest why the pituitary gland is sometimes called the master gland of the endocrine system. [3 marks]

4 Suggest what would happen if the pituitary gland:
a did not produce enough growth hormone in a child [2 marks]
b continued to produce lots of growth hormone in an adult. [2 marks]

B11.2 The control of blood glucose levels

Learning objectives

After this topic, you should know:

- the role of the pancreas in monitoring and controlling blood glucose concentration
- how insulin controls blood glucose levels in the body
- (H) how glucagon and insulin interact to control blood glucose levels
- what causes diabetes.

Study tip

Know the difference between:

- glucose – the sugar used in respiration
- glycogen – a storage carbohydrate found in the liver and muscles
- (H) glucagon – a hormone that stimulates the liver to break down glycogen to glucose.

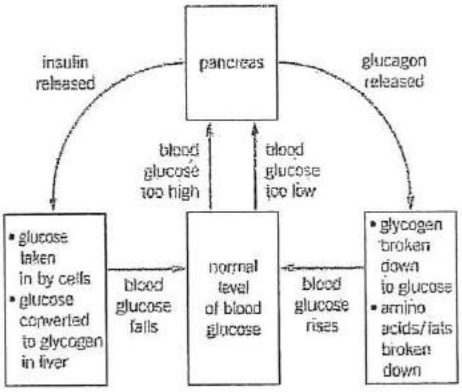


Figure 1 *Negative feedback control of blood glucose levels using insulin and glucagon*

It is essential that your cells have a constant supply of the glucose they need for respiration. To achieve this, one of your body systems responds to changes in your blood glucose levels and controls it to within very narrow limits. This is an example of homeostasis in action.

Insulin and the control of blood glucose levels

When you digest a meal, large amounts of glucose pass into your blood. Without a control mechanism, your blood glucose levels would vary significantly. They would range from very high after a meal to very low several hours later – so low that cells would not have enough glucose to respire.

This situation is prevented by your pancreas. The pancreas is a small pink organ found under your stomach. It constantly monitors and controls your blood glucose concentration using two hormones. The best known of these is **insulin**.

When your blood glucose concentration rises after you have eaten a meal, the pancreas produces insulin. Insulin allows glucose to move from the blood into your cells where it is used. Soluble glucose is also converted to an insoluble carbohydrate called glycogen. Insulin controls the storage of glycogen in your liver and muscles. Stored glycogen can be converted back into glucose when it is needed. As a result, your blood glucose stays stable within a narrow concentration range.

When the glycogen stores in the liver and muscles are full, any excess glucose is converted into lipids and stored. If you regularly take in food that results in having more glucose than the liver and muscles can store as glycogen, you will gradually store more and more of it as lipids. Eventually you may become obese.

Glucagon and control of blood glucose levels

Higher

The control of your blood glucose doesn't just involve insulin. When your blood glucose concentration falls below the ideal range, the pancreas secretes another hormone called **glucagon**. Glucagon makes your liver break down glycogen, converting it back into glucose. In this way, the stored glucose is released back into the blood.

By using two hormones and the glycogen store in your liver, your pancreas keeps your blood glucose concentration fairly constant. It does this using negative feedback control, which involves switching between the two hormones (Figure 1).

Figure 2 shows a model of your blood glucose control system where the blood glucose is a tank. It has both controlled and uncontrolled inlets and outlets. In every case, any control is given by the hormones insulin and glucagon.

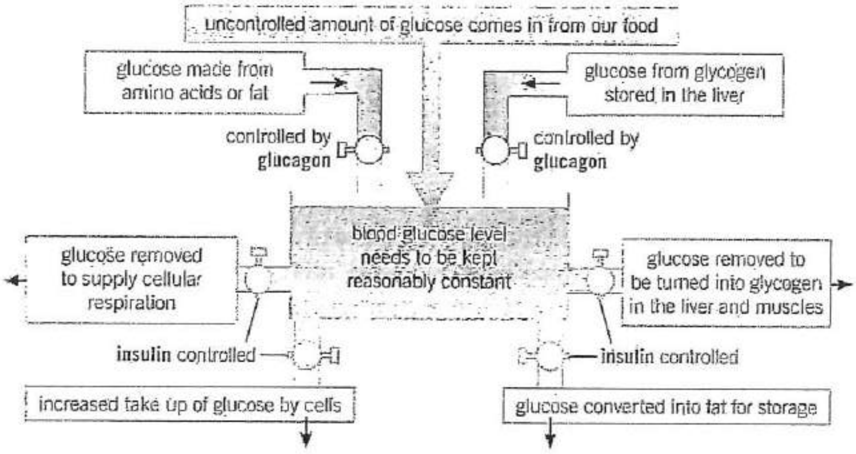


Figure 2 *A model of your blood glucose control system*

What causes diabetes?

If your pancreas does not make enough (or any) insulin, your blood glucose concentration is not controlled. You have **type 1 diabetes**.

Without insulin your blood glucose levels get very high after you eat. Eventually your kidneys excrete glucose in your urine. You produce lots of urine and feel thirsty all the time. Without insulin, glucose cannot get into the cells of your body, so you lack energy and feel tired. You break down fat and protein to use as fuel instead, so you lose weight. Type 1 diabetes is a disorder that usually starts in young children and teenagers. There seems to be a genetic element to the development of the disease.

Type 2 diabetes is another, very common type of diabetes. It gets more common as people get older and is often linked to obesity, lack of exercise, or both. There is also a strong genetic tendency to develop type 2 diabetes. In type 2 diabetes, the pancreas still makes insulin, although it may make less than your body needs. Most importantly, your body cells stop responding properly to the insulin you make. In countries such as the UK and the USA, levels of type 2 diabetes are rising rapidly as obesity becomes more common.

1 Define the terms:
a insulin [1 mark] **b** diabetes [1 mark] **c** glycogen. [1 mark]

2 **a** Explain how the pancreas responds when blood glucose levels go above the ideal range. [3 marks]
b (H) Explain how the pancreas responds when blood glucose levels go below the ideal range. [3 marks]
c Why is it so important to control the level of glucose in your blood? [3 marks]

3 Explain the difference between type 1 and type 2 diabetes. [6 marks]

4 (H) Compare and contrast the roles of insulin and glucagon in controlling the body's blood glucose levels. [6 marks]

Key points

- Your blood glucose concentration is monitored and controlled by your pancreas.
- The pancreas produces the hormone insulin, which allows glucose to move from the blood into the cells and to be stored as glycogen in the liver and muscles.
- (H) The pancreas also produces glucagon, which allows glycogen to be converted back into glucose and released into the blood.
- (H) Glucagon interacts with insulin in a negative feedback cycle to control glucose levels.
- In type 1 diabetes, the blood glucose may rise to fatally high levels because the pancreas does not secrete enough insulin.
- In type 2 diabetes, the body stops responding to its own insulin.

B11.3 Treating diabetes

Learning objective

After this topic, you should know:

- the differences in the way type 1 and type 2 diabetes are treated.

Figure 1 *The treatment of type 1 diabetes involves regular blood glucose tests and insulin injections to keep the blood glucose levels constant*

Synoptic links

You learnt about stem cells and some of the issues surrounding their use in Topic B2.3 and Topic B2.4.

Synoptic link

For more information on the links between obesity and diseases such as type 2 diabetes, look back to Topic B7.4.

Before there was any treatment for diabetes, people would waste away. Eventually they would fall into a coma and die.

The treatment of diabetes has developed over the years and continues to improve today. There are now some very effective ways of treating people with diabetes. However, over the long term, even well-managed diabetes may cause problems with the circulatory system, kidneys, or eyesight.

Treating type 1 diabetes

If you have type 1 diabetes, you need replacement insulin before meals. Insulin is a protein that would be digested in your stomach, so it is usually given as an injection to get it into your blood.

This injected insulin allows glucose to be taken into your body cells and converted into glycogen in the liver. This stops the concentration of glucose in your blood from getting too high. Then, as the blood glucose levels fall, the glycogen is converted back to glucose. As a result, your blood glucose levels are kept as stable as possible.

If you have type 1 diabetes, you also need to be careful about the levels of carbohydrate you eat. You need to have regular meals. Like everyone else, you need to exercise to keep your heart and blood vessels healthy. However, taking exercise needs careful planning to keep your blood glucose levels steady. Your cells need enough glucose to respire more rapidly to produce the energy required for your muscles to work.

Insulin injections treat diabetes successfully but they do not cure it. Until a cure is developed, someone with type 1 diabetes has to inject insulin every day of their life.

Curing type 1 diabetes

Scientists and doctors want to find a treatment that means people with diabetes never have to take insulin again.

- Doctors can transplant a pancreas successfully. However, the operations are difficult and risky. Only a few hundred pancreas transplants take place each year in the UK. There are 250 000 people in the UK with type 1 diabetes, but not enough pancreas donors are available. In addition, the patient exchanges one medicine (insulin) for another (immunosuppressants).
- Transplanting the pancreatic cells that make insulin from both dead and living donors has been tried, with limited success so far.

In 2005, scientists produced insulin-secreting cells from embryonic stem cells and used them to cure diabetes in mice. In 2008, UK scientists discovered a completely new technique. Using genetic engineering, they turned mouse pancreas cells that normally make enzymes into insulin-producing cells. Other groups are using adult stem cells from patients with diabetes to try the same technique.

Scientists hope that eventually they will be able to genetically engineer faulty human pancreatic cells so that they work properly. Then they will be able to return them to the patient with no rejection issues. It still seems likely that the easiest cure will be to use stem cells from human embryos that have been specially created for the process. However, for some people, this is not ethically acceptable.

Much more research is needed. However, scientists hope that type 1 diabetes will soon be an illness they can cure rather than just manage.

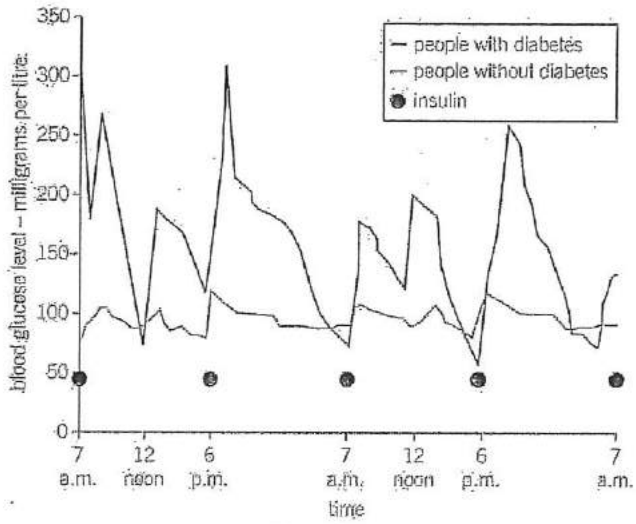


Figure 2 *The blood glucose levels of people with and without diabetes over two days. The yellow band shows normal blood glucose levels and the peaks show the effect of food intake. Insulin injections cannot mimic natural control, but enable people with diabetes to live active lives.*

Treating type 2 diabetes

Type 2 diabetes is linked to obesity, lack of exercise, and old age. If you develop the disease, your body cells no longer respond to any insulin made by the pancreas. This can often be treated without needing to inject insulin. Many people can restore their normal blood glucose balance by taking three simple steps:

- eating a balanced diet with carefully controlled amounts of carbohydrates
- losing weight
- doing regular exercise.

If this doesn't work, there are drugs that:

- help insulin work better on the body cells
- help your pancreas make more insulin
- reduce the amount of glucose you absorb from your gut.

If none of these treatments work, you will probably need insulin injections.

Type 2 diabetes usually affects older people. However, it is becoming more and more common in young people who are very overweight.

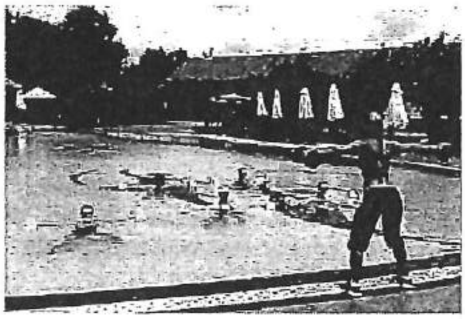


Figure 3 *Losing weight and taking exercise are simple ways to help overcome type 2 diabetes*

1 State three differences between type 1 diabetes and type 2 diabetes. [3 marks]

2 It is a common misconception that diabetes is treated only by using insulin injections.

  a Explain why this is not always true for people with type 1 diabetes. [3 marks]

  b Explain why treatment with insulin injections is relatively uncommon for people with type 2 diabetes. [3 marks]

3 Transplanting a pancreas to replace natural insulin production seems to be the ideal treatment for type 1 diabetes. Compare this treatment with insulin injections and explain why it is not more widely used. [4 marks]

4 Explain the different methods used to treat type 1 diabetes and type 2 diabetes, linking these methods to how the types of diabetes are caused. [6 marks]

Key points

- Type 1 diabetes is normally controlled by injecting insulin to replace the hormone that is not made in the body.
- Type 2 diabetes is often treated by a carbohydrate-controlled diet and taking more exercise. If this doesn't work, drugs may be needed.

B11.4 The role of negative feedback

Learning objectives

After this topic, you should know:

- what adrenaline and thyroxine do in the body
- the importance of negative feedback systems.

Many hormones in your body are controlled as part of negative feedback systems. These involve the coordination of changes in the internal environment of your body with the amounts of hormone produced.

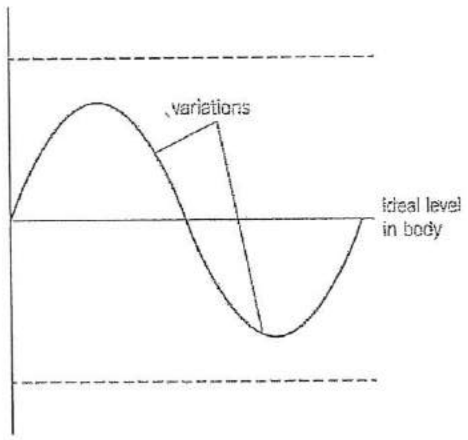
Negative feedback

Put simply, negative feedback systems work to maintain a steady state.

If a factor in the internal environment increases, changes take place to reduce it and restore the original level.

If a factor in the internal environment decreases, changes take place to increase it and restore the original level.

Whatever the initial change, in negative feedback the response causes the opposite (Figure 1). The principle is easier to understand when you see working examples. Many hormones are involved in negative feedback systems, including insulin and glucagon, most female sex hormones, and thyroxine (see below).



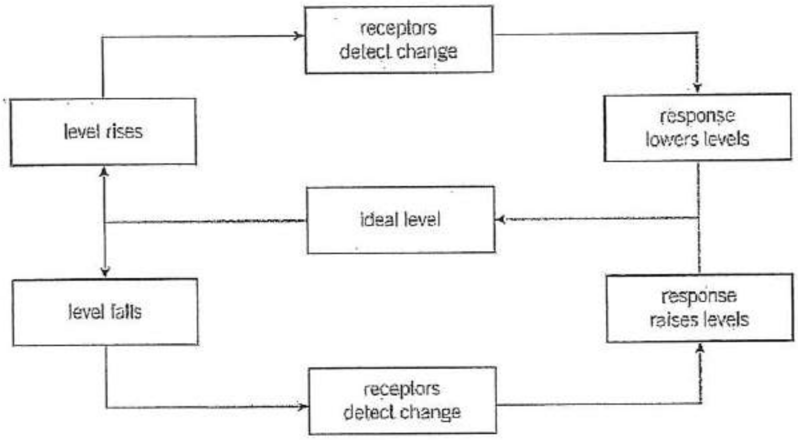


Figure 1 *A negative feedback loop means values will vary around a normal level within a limited range*

Thyroxine and negative feedback

The thyroid gland in your neck uses iodine from your diet to produce the hormone thyroxine. This controls the basal metabolic rate of your body – how quickly substances are broken down and built up, how much oxygen your tissues use, and how the brain of a growing child develops. Thyroxine plays an important part in growth and development. In adults the level of thyroxine in the blood usually remains relatively stable. This happens as a result of a negative feedback control involving the pituitary gland and the hormone it produces – thyroid stimulating hormone or TSH.

If levels of thyroxine in the blood begin to fall, it is detected by sensors in the brain. As a result, the amount of TSH released from the pituitary gland increases. This is a negative feedback system. TSH stimulates the production of thryoxine by the thyroid gland. As the level of thyroxine goes up, it is detected by the sensors and in turn the level of TSH released falls.

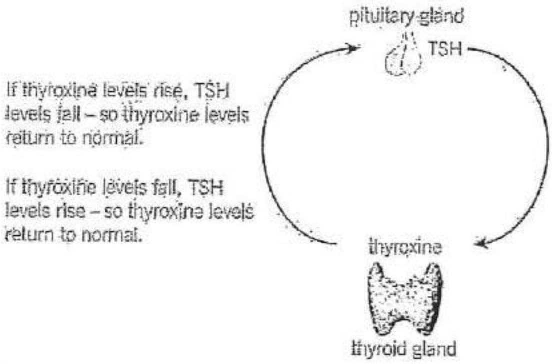


Figure 2 *The levels of thyroxine in your body are kept within narrow boundaries by a negative feedback loop*

Adrenaline

Not all hormones are involved in such clear-cut negative feedback systems. If you are stressed, angry, excited, or frightened your body needs to be ready for action. Your adrenal glands, located at the top of your kidneys, secrete lots of adrenaline that is carried rapidly around the body in your blood, affecting lots of organs. Adrenaline causes:

- your heart rate and breathing rate to increase
- stored glycogen in the liver to be converted to glucose for respiration
- the pupils of your eyes to dilate to let in more light
- your mental awareness to increase
- blood to be diverted away from your digestive system to the big muscles of the limbs.

Adrenaline boosts the delivery of oxygen and glucose to your brain and muscles, preparing your body for flight or fight. Once the danger is over, the raised levels of awareness are no longer needed. The adrenal glands stop releasing adrenaline and your systems return to their resting levels. This does not involve a negative feedback loop.

1 Describe how a negative feedback system works. [4 marks]

2 Compare the role of thyroxine in the body and the way it is controlled with the role and control system for adrenaline. [4 marks]

3 In Ethiopia up to 40% of the population, both adults and children, do not get enough iodine in their diet. Around 40% of the population also have non-communicable diseases caused by low thyroxine levels.

  a Explain why these two facts are linked. [3 marks]

  b Suggest a simple way of overcoming the problems of diseases linked to low thyroxine levels. [2 marks]

Go further

The control of the hormones involved in homeostasis in your body is very complex. Simple feedback systems are rare. There are often interactions between the hypothalamus, the pituitary gland, and other exocrine glands, as well as the specific endocrine glands, in the control of hormone levels in the body.

Key points

- Thyroxine from the thyroid gland stimulates the basal metabolic rate. It plays an important role in growth and development.
- Adrenaline is produced by the adrenal glands in times of fear or stress. It increases the heart rate and boosts the delivery of oxygen and glucose to the brain and muscles, preparing the body for 'fight or flight'.
- Thyroxine is controlled by negative feedback whereas adrenaline is not.

B11.5 Human reproduction

Learning objectives

After this topic, you should know:

- the main human reproductive hormones
- how hormones control the changes at puberty.

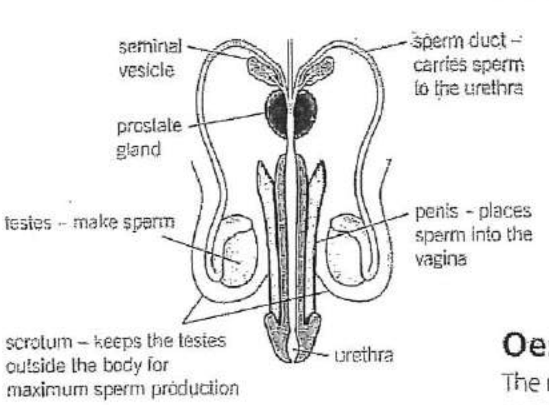


Figure 1 *Male reproductive organs*

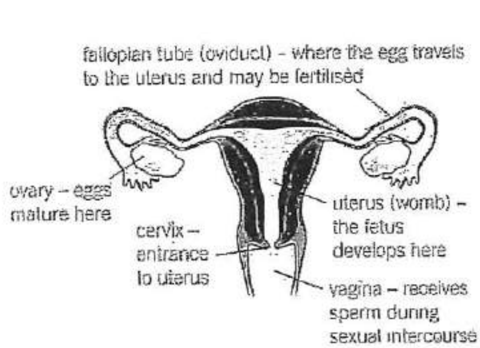


Figure 2 *The female reproductive system*

The big physical changes that make boys and girls look very different take place at the time of puberty. This is when the reproductive organs become active and the body takes on its adult form. Hormones play an important part in human reproduction at every stage.

Hormones and puberty

During puberty, the reproductive hormones control the development of the secondary sexual characteristics. The primary sexual characteristics are the ones you are born with. Primary sex characteristics are the ovaries in girls and the testes in boys. These reproductive organs produce the female and male sex hormones and the special sex cells or gametes that join together in reproduction. To understand the changes that take place in puberty it helps to understand the basic female and male anatomy (Figure 1 and Figure 2).

The timing of puberty and the order and rate of the changes varies but the basic changes are the same for everyone.

Oestrogen and puberty in females

The main female reproductive hormone is **oestrogen**, produced by the **ovaries**. Rising oestrogen levels trigger the development of the female secondary sexual characteristics usually between the ages of 8 and 14 years. The main changes include a growth spurt; the growth of hair under the arms and pubic hair; the breasts develop; the external genitals grow and the skin darkens; a female pattern of fat is deposited on the hips, buttocks and thighs; the brain changes and matures; mature ova start to form every month in the ovaries, the uterus grows and becomes active and menstruation begins.

The menstrual cycle

Once a girl has gone through puberty she will have a monthly menstrual cycle. Each month, eggs begin to mature in the ovary. At the same time the uterus produces a thickened lining ready for a pregnancy. Every 28 days a mature egg is released. This is called **ovulation**. If the egg is not fertilised, around 14 days later the lining of the uterus is shed along with the egg. This is the monthly period and this also takes place at approximately 28-day intervals. Several hormones are involved in controlling the menstrual cycle:

- follicle stimulating hormone (FSH) causes the eggs in the ovary to mature (the eggs grow surrounded by cells called the follicle)
- luteinising hormone (LH) stimulates the release of the egg at ovulation
- oestrogen and progesterone stimulate the build-up and maintenance of the uterus lining.

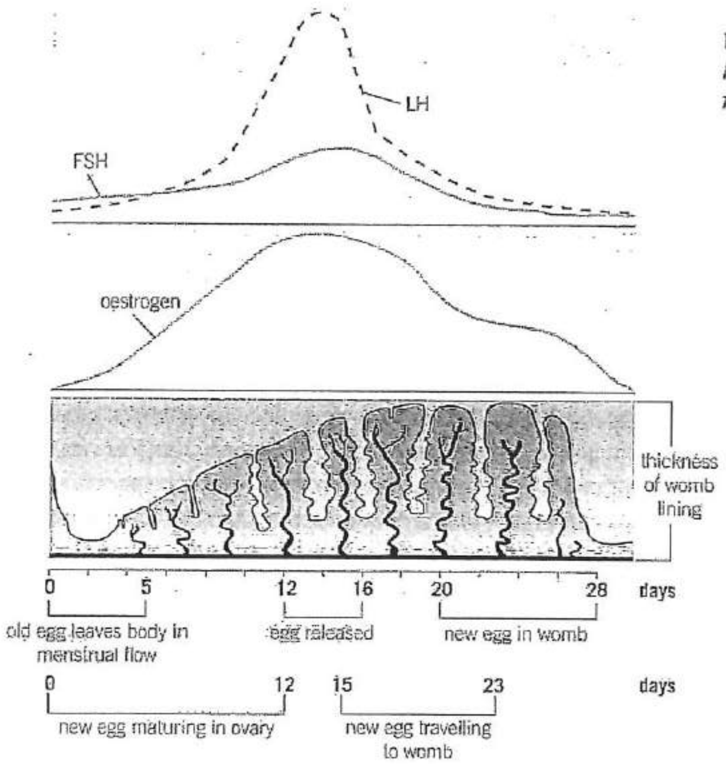


Figure 3 The changing levels of the female sex hormones control the different stages of the menstrual cycle

Female fertility

The ovaries of a baby girl contain all the eggs she will ever have. After puberty, eggs mature and are released every month, for an average of 35–40 years, except if she is pregnant. Eventually the supply of eggs runs out and the woman goes through the menopause – she can no longer have children. Approaching the menopause, a woman is less fertile and has a higher risk of having a baby with genetic problems.

Testosterone and puberty in males

The main male reproductive hormone is **testosterone**, produced by the testes. As levels of testosterone rise, all kinds of changes are triggered and the male secondary sexual characteristics develop. Boys usually go into the first stages of puberty slightly later than girls, between the ages of 9 and 15. The main changes include a growth spurt; pubic hair, underarm hair and facial hair grow; the larynx gets bigger and the voice breaks; the external genitalia and the skin darkens; the testes grow and become active, producing sperm throughout life; the shoulders and chest broaden as muscle develops; and the brain matures.

1 State three reasons why hormones are important in human reproduction. [3 marks]

2 Describe three similarities and three differences in puberty between boys and girls. [6 marks]

3 a Describe the role of hormones in the menstrual cycle. [4 marks]
  b State the differences between the production of mature eggs in women and mature sperm in men. [6 marks]

Key points

- During puberty reproductive hormones cause secondary sexual characteristics to develop.
- Oestrogen is the main female reproductive hormone produced by the ovary. At puberty eggs begin to mature in the ovary and one is released approximately every 28 days at ovulation.
- Testosterone is the main male reproductive hormone produced by the testes and stimulates sperm production.
- Hormones involved in the menstrual cycle of a woman include follicle stimulating hormone (FSH), luteinising hormone (LH), oestrogen, and progesterone.

Higher tier

B11.6 Hormones and the menstrual cycle

Learning objectives

After this topic, you should know:

- the roles of hormones in human reproduction
- how hormones interact to control the menstrual cycle.

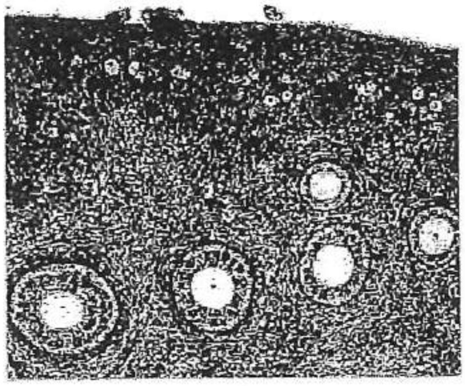


Figure 1 *You can see the ova (eggs) developing in the follicles in this light micrograph of a piece of ovarian tissue*

Figure 2 *The egg cannot move itself but the cilia of the fallopian tubes beat to move it along to the uterus (magnification: x2100)*

The levels of testosterone in a man's body remain relatively constant after puberty, and sperm are made continuously in the testes. In contrast, a baby girl is born with all of the immature eggs she will ever have already in place in her ovaries. After puberty, a small number of eggs mature each month until one (or occasionally two) is released into the oviduct. A woman's menstrual cycle is a good example of control by hormones. The levels of different hormones made in the pituitary gland and ovaries rise and fall in a regular pattern, affecting the way the body of the woman works.

The menstrual cycle

The average length of the menstrual cycle is about 28 days. Each month the lining of the uterus (womb) thickens ready to support a developing baby. At the same time, eggs start maturing in the follicles of the ovary.

About 14 days after the eggs start maturing, one is released from the ovary in ovulation. The lining of the uterus stays thick for several days after the egg has been released.

If the egg is fertilised by a sperm, then pregnancy may take place. The lining of the uterus provides protection and food for the developing embryo. If the egg is not fertilised, about 14 days after ovulation the lining of the uterus and the egg are shed from the body in the monthly period.

Control of the menstrual cycle

The complex events of the menstrual cycle are coordinated by the interactions of the four different hormones given in Topic B11.5. Once a month, a surge of hormones from the pituitary gland in the brain starts egg maturation in the ovaries. The hormones also stimulate the ovaries to produce the female sex hormone oestrogen.

Follicle stimulating hormone (FSH) is secreted by the pituitary gland. It makes eggs mature in their follicles in the ovaries. It also stimulates the ovaries to produce hormones including oestrogen.

Oestrogen is made and secreted by the ovaries in response to FSH. It stimulates the lining of the uterus to grow again after menstruation in preparation for pregnancy. High levels of oestrogen inhibit the production of more FSH and stimulate the release of LH.

Luteinising hormone (LH) from the pituitary gland stimulates the release of a mature egg from the ovary. Once ovulation has taken place, LH levels fall again.

Progesterone is secreted by the empty egg follicle in the ovary after ovulation. It is one of the hormones that helps to maintain a pregnancy if the egg is fertilised. Progesterone inhibits both FSH and LH and it maintains the lining of the uterus in the second half of the cycle, so it is ready to receive a developing embryo if the egg is fertilised.

The hormones produced by the pituitary gland and the ovary act together to control what happens in the menstrual cycle. As the oestrogen levels rise, they inhibit the production of FSH and encourage the production of LH by the pituitary gland. When LH levels reach a peak in the middle of the cycle, they stimulate the release of a mature egg.

FSH and LH are then suppressed and the body is kept ready for pregnancy until it becomes clear that the egg is not fertilised.

The levels of all the hormones then drop and the lining of the uterus pulls away and is lost from the body. At this stage a new cycle begins and the levels of FSH and oestrogen start to build up again.

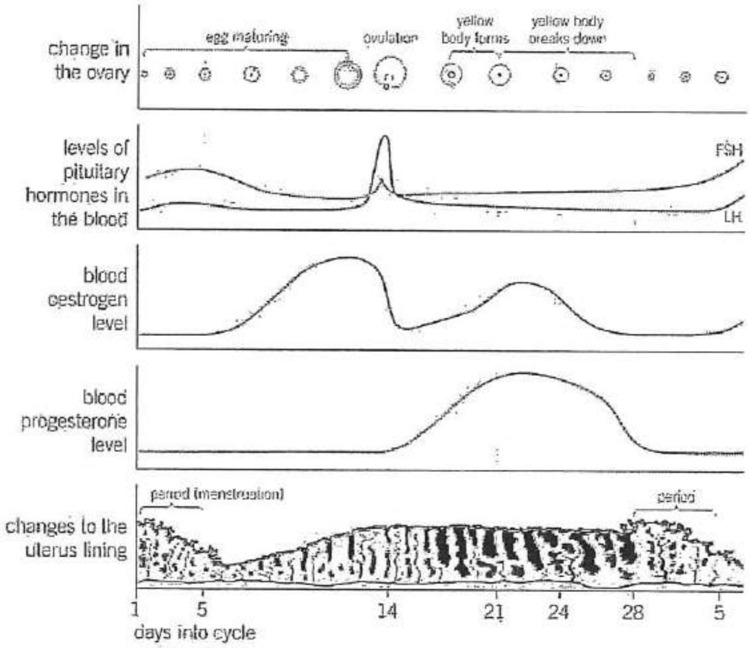


Figure 3 *The main events of the menstrual cycle*

1 a State the four hormones that control the menstrual cycle. [4 marks]
  b State why the lining of the uterus builds up each month. [1 mark]

2 Look at Figure 3 and answer the following questions.
  a On which days is the woman having a menstrual period? [1 mark]
  b Explain what happens to the levels of FSH and LH during the cycle. [4 marks]
  c Name the hormone that controls the build up of the lining of the uterus. [1 mark]

3 Explain the main events of the menstrual cycle, identifying the stage where a woman is most likely to become pregnant. [6 marks]

Study tip

Be clear on the difference between the female reproductive hormones:

FSH
- causes eggs to mature
- stimulates the ovary to produce oestrogen.

LH
- triggers ovulation.

Oestrogen
- causes the lining of the uterus to develop
- inhibits the release of FSH
- stimulates the release of LH.

Progesterone
- maintains the lining of the uterus
- inhibits the release of both FSH and LH.

Key points

- The interactions of four hormones control the maturing and release of an egg from the ovary and the build-up of the lining of the uterus in the menstrual cycle.
- FSH from the pituitary stimulates eggs to mature in the follicles of the ovary and the ovary to produce oestrogen.
- Oestrogen secreted by the ovaries stimulates the growth of the lining of the uterus and the release of LH and inhibits FSH.
- LH stimulates ovulation.
- Progesterone is produced by the empty follicle after ovulation. It maintains the lining of the uterus for around 10 days and inhibits FSH and LH.

B11.7 The artificial control of fertility

Learning objectives

After this topic, you should know:

- a number of different methods of hormonal and non-hormonal contraception.

To prevent pregnancy, you need to prevent the egg and sperm meeting or a fertilised egg implanting in the uterus. This is known as **contraception**. The different methods all have advantages and disadvantages.

Hormone-based contraception

Scientists have worked out a number of different ways to use the hormones of the menstrual cycle, or synthetic versions of them, to prevent pregnancy.

Oral contraceptives, often referred to as the contraceptive pill, use female hormones to prevent pregnancy. The mixed pill contains low doses of oestrogen along with some progesterone. The hormones inhibit the production and release of FSH by the pituitary gland, affecting the ovaries, so no eggs mature, preventing pregnancy. The pill hormones also stop the uterus lining developing, preventing implantation. They also make the mucus in the cervix thick to prevent sperm getting through. The contraceptive pill is easy to use but there is a slight risk of side effects, including raised blood pressure, thrombosis, and breast cancer.

Some contraceptive pills contain only progesterone. They have fewer side effects than the mixed pill. Women must take the pill very regularly, especially the progesterone-only pill. If they don't, the artificial hormone levels drop and their body's own hormones can take over very quickly. This can lead to the unexpected release of an egg – and an unexpected baby!

There are alternative ways of delivering hormones to prevent pregnancy. A contraceptive implant can last up to three years. A tiny tube is inserted under your skin by a doctor and slowly releases progesterone. This is 99.95% effective! Contraceptive injections also use progesterone but they only last about 12 weeks.

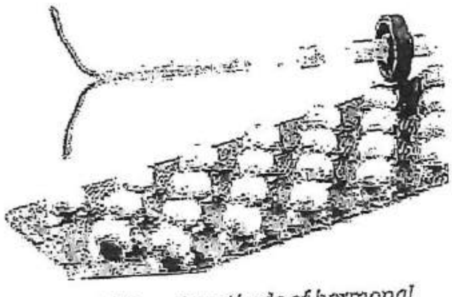


Figure 1 *Different methods of hormonal contraception*

The contraceptive patch, like the mixed pill, contains a mixture of oestrogen and progesterone. You stick the patch to your skin, replacing it every 7 days, and the hormones are absorbed directly into your blood stream. All of these methods prevent an egg maturing and being released, as well as affecting the uterus lining and the mucus in the cervix.

Chemical methods

Chemicals that kill or disable sperm are known as spermicides. They are readily available but are not very effective at preventing pregnancy.

Barrier methods

Barrier methods of contraception prevent the sperm reaching the egg. A condom is a thin latex sheath placed over the penis during intercourse to collect the semen and prevent the egg and sperm meeting. They have no side effects and do not need medical advice. Condoms offer some protection against sexually transmitted diseases such as syphilis and HIV/AIDS. They can, however, get damaged and let sperm through.

A diaphragm or cap is a thin rubber diaphragm placed over the cervix before sex to prevent the entry of sperm. Like condoms, they have no side effects but must be fitted by a doctor initially. If the cap is not positioned correctly, sperm may get past and reach the egg. Barrier methods work better combined with spermicide.

Intrauterine devices

Intrauterine devices are small structures inserted into the uterus by a doctor. They last for 3–5 years although they can be removed at any time if you want to get pregnant. Some intrauterine devices contain copper and prevent any early embryos implanting in the lining of the uterus. Others contain progesterone, releasing it slowly to prevent the build-up of the uterus lining and to thicken the mucus of the cervix. They are very effective but they may cause period problems or infections.

Abstinence

If people do not have sex they will not get pregnant. Some religious groups do not accept the use of artificial methods of contraception. Abstaining from intercourse around ovulation or when an egg is in the oviduct means sperm cannot fertilise the egg – this is known as the rhythm method. This method has no side-effects but it is very unreliable. Ovulation indicators make it more effective.

Surgical methods

If people do not want any more children, they can be surgically sterilised. In men the sperm ducts are cut and tied, preventing sperm getting into the semen. This is called a vasectomy.

In women the oviducts are cut or tied to prevent the egg reaching the uterus and the sperm reaching the egg. Although this gives effective, permanent contraception with no risk of human error, women need a general anaesthetic for the surgery.

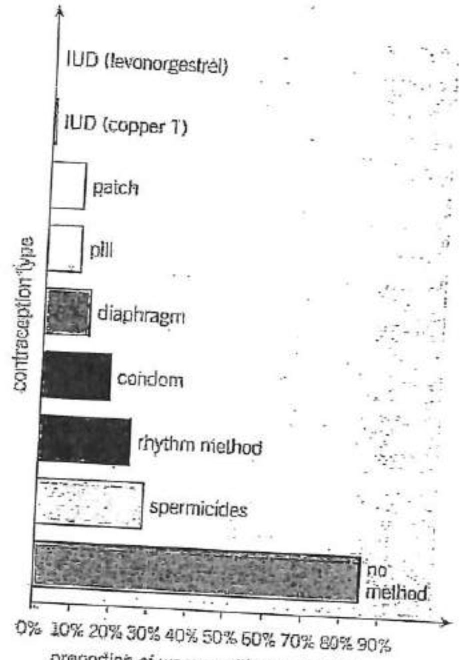


Figure 2 *Failure rates for different methods of birth control based on data from the American Academy of Paediatrics*

1 Define the term contraception. [1 mark]

2 The progesterone-only pill, the contraceptive implant, and the contraceptive patch are all forms of contraceptive.
  a State one similarity between each contraceptive. [1 mark]
  b For each contraceptive, state one way it is different. [3 marks]
  c Explain which of these three methods is likely to be the most effective contraceptive and why. [3 marks]

3 Compare the effectiveness of the three main types of contraception – hormone-based contraception, barrier methods, and surgical methods. [3 marks]

Key points

- Fertility can be controlled by a number of hormonal and non-hormonal methods of contraception.
- Contraceptive methods include oral contraceptives, hormonal injections, implants and patches, barrier methods such as condoms and diaphragms, intrauterine devices, spermicidal agents, abstinence, and surgical sterilisation.

B11.8 Infertility treatments

Learning objectives

After this topic, you should know:

- how hormones can be used to treat infertility.

Study tip

A combination of FSH and LH can be used in fertility treatments to cause eggs to mature in the ovary and to trigger ovulation.

In the UK as many as one couple in six have problems having a family when they want one. There are many possible reasons for this infertility. It may be linked to a lack of female hormones, to damaged oviducts, or to a lack of sperm in the semen. About a third of cases of infertility are due to problems with the female reproductive system, about a third due to the male system, and about a third are hard to explain, with both partners being a bit less fertile than normal. Common causes of infertility are obesity and eating disorders such as anorexia nervosa, but one of the most common causes of infertility is age. Increasingly, couples wait until they are in their late thirties to have children, and then find that they cannot conceive naturally.

Lack of ovulation

Some women want children but do not make enough FSH to stimulate the maturation of the eggs in their ovaries. Fortunately, artificial FSH can be used as a fertility drug. It stimulates the eggs in the ovary to mature and also triggers oestrogen production. An artificial form of LH can then be used to trigger ovulation. If a woman who is not ovulating as a result of a lack of her own FSH is treated in this way, she may be able to get pregnant naturally. In the early days of using fertility drugs there were big problems with the doses used. In 1971, an Italian doctor removed 15 four-month-old foetuses (ten girls and five boys) from the womb of a 35-year-old woman after treatment with fertility drugs. Not one of them survived. Now the doses are much more carefully controlled and most people using fertility drugs end up with just one or two babies.

In vitro fertilisation

Fertility drugs are also used in IVF (*in vitro* fertilisation). IVF is a form of fertility treatment used if the oviducts have been damaged or blocked by infection, if a donor egg has to be used, or if there is no obvious cause for long-term infertility.

In some cases a man produces very few sperm or the sperm do not mature properly. Individual sperm may be injected into an egg during the IVF process.

In all these cases it would not be possible to get pregnant naturally.

Fortunately, doctors can now help.

- They give the mother synthetic FSH to stimulate the maturation of a number of eggs at the same time, followed by LH to bring the eggs to the point of ovulation.
- They collect the eggs from the ovary of the mother and fertilise them with sperm from the father outside the body in the laboratory.
- The fertilised eggs are kept in special solutions in a warm environment to develop into tiny embryos.
- At the stage when they are minute balls of cells, one or two of the embryos are inserted back into the uterus of the mother. In this way they bypass the faulty tubes.

Table 1 *Data from 2010 showing the decreasing success rate of IVF as the mother gets older*

Age of mother	IVF % success rate
Under 35	32.2
35–37	27.7
38–39	20.8
40–42	13.6
43–44	5
Over 44	1.9

Modern infertility treatments such as these rely on advanced microscopy techniques. It takes a high level of manipulative skill and a high magnification to work on single eggs and sperm, or early embryos, without damaging them.

The advantages and disadvantages of fertility treatment

The use of hormones to help overcome infertility has been a major scientific breakthrough. It gives women and men who would otherwise be infertile the chance to have a baby of their own. But like most things there are advantages and disadvantages. Here are some points to think about:

IVF is expensive both for society, if it is provided by the National Health Service (NHS), and for individuals – many people end up paying thousands of pounds for repeated cycles of treatment.

It is not always successful. The older the parents, the less likely it is that they will have a baby (Table 1). Using donor eggs from younger women or donor sperm from younger men can help the success rate but then the baby is not biologically the parents' child.

The use of fertility drugs can have some health risks for the mother. The process of IVF is very emotionally and physically stressful.

IVF increases the chances of a multiple pregnancy. On average, 1 in 5 IVF pregnancies is a multiple pregnancy. The figure for natural pregnancies is 1 in 80. Multiple births increase the risks for both mothers and babies, and are more likely to lead to stillbirths and other problems including very premature births. It costs hospitals a lot of money to keep very small premature babies alive and if they survive many will have permanent and often severe disabilities.

The mature eggs produced by a woman using fertility drugs may be collected and stored, or fertilised and stored, until she wants to get pregnant later. But this raises ethical problems if the woman dies, the relationship breaks up, or one of the parents no longer wants the eggs or embryos.

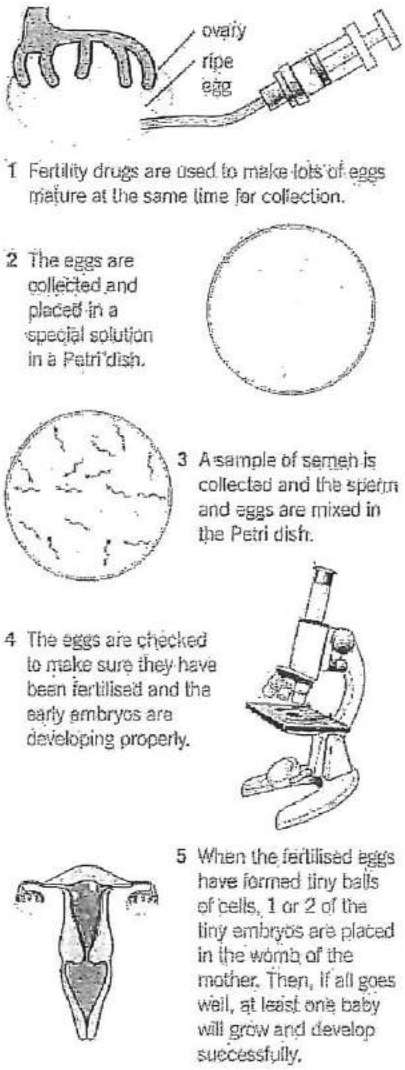


Figure 1 *New reproductive technology using hormones and IVF helps thousands of otherwise infertile couples to have babies each year*

1 What is IVF? [2 marks]

2 Explain how artificial female hormones can be used to:
   a help people overcome infertility and conceive naturally [3 marks]
   b help people overcome infertility and conceive through IVF. [3 marks]

3 a Draw a graph to show the effect of age on the chances of a woman having a baby successfully using IVF. [4 marks]
   b Some people think that IVF treatment should not be offered to people over the age of 40. Suggest arguments for and against this idea. [6 marks]

4 Suggest and explain some advantages and disadvantages of using artificial hormones to control female fertility? [6 marks]

Key points

- FSH and LH can be used as a fertility drug to stimulate ovulation in women with low FSH levels.
- In vitro fertilisation (IVF) uses FSH and LH to stimulate maturation of ova that are collected, fertilised, allowed to start development, and replaced in the uterus.
- IVF is emotionally and physically stressful, often unsuccessful, and can lead to risky multiple births.

B11 Hormonal coordination

Summary questions

1 Figure 1 shows the blood glucose levels of a person without diabetes and someone with type 1 diabetes managed with regular insulin injections. They both eat at the same times.

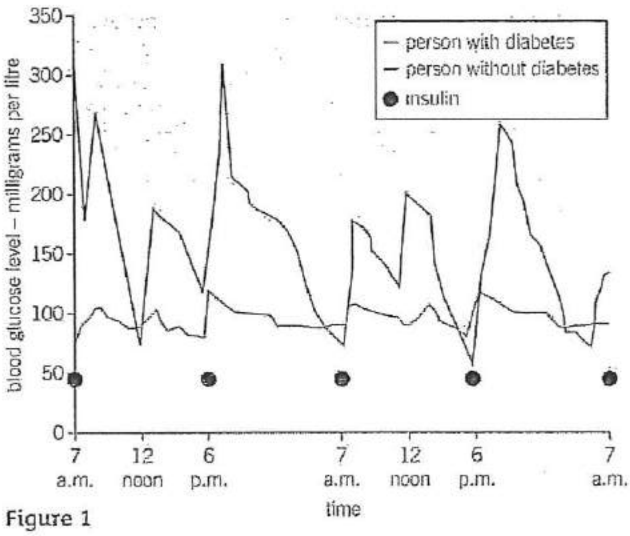


Figure 1

Use Figure 1 to help you answer these questions:

a What happens to the blood glucose levels of both individuals after eating? [1 mark]

b What is the range of blood glucose concentration of the person without diabetes? [1 mark]

c What is the range of blood glucose concentration of the person with diabetes? [1 mark]

d Figure 1 shows the effect of regular insulin injections on the blood glucose level of someone with diabetes. Why are the insulin injections important to their health and wellbeing? What limitations are suggested by the data? [4 marks]

e People with diabetes have to monitor the amount of carbohydrate in their diet. Explain why. [4 marks]

2 **a** Describe the main events of the menstrual cycle. [6 marks]

b (H) Explain the role of the following hormones in the menstrual cycle:

i FSH [2 marks]

ii oestrogen [3 marks]

iii LH [2 marks]

iv progesterone. [2 marks]

3 **a** What are secondary sexual characteristics? [2 marks]

b State three changes at puberty that are common to both boys and girls. [3 marks]

c State two changes that occur during puberty that are unique to girls. [2 marks]

d State two changes that occur during puberty that are unique to boys. [2 marks]

e Which hormone is important in the development of the secondary sexual characteristics in both females and males. Explain its role. [5 marks]

f (H) Explain how the hormones interact to bring about the main changes in the body during the menstrual cycle. [6 marks]

4 **a** Explain how artificial hormones can be used in pills to prevent people getting pregnant. [4 marks]

b Describe three other ways contraceptive hormones can be given and give one advantage for each method. [6 marks]

c (H) Explain how artificial hormones can be used to help treat infertility. [4 marks]

d (H) Compare the way artificial hormones are used in contraception and infertility treatment. [4 marks]

5 (H) Many hormone systems in the body are controlled by negative feedback systems.

a Using the control of thyroxine levels in the body as an example, describe how a negative feedback system works. [5 marks]

b Explain why negative feedback control is so important in maintaining homeostasis. [5 marks]

c Not all hormones are controlled by negative feedback systems. Explain the role of adrenaline in the response of your body to stress. [6 marks]

d Discuss the importance of the lack of a negative feedback control system for adrenaline. [5 marks]

Practice questions

01 **Table 1** shows the changes in the blood glucose concentration of a person with type 1 diabetes after they ate a meal.

Table 1

Time in hours	Blood glucose concentration in units
0.0	8.0
0.5	15.0
1.0	18.0
1.5	19.4
2.0	17.6

01.1 Plot the data in **Table 1** as a line graph. Join the points with straight lines. [5 marks]

01.2 In a person who does not have diabetes, the blood glucose concentration would be between 3.5 and 5.5 units before meals and below 8 units two hours after eating a meal.
Use this information to sketch a line on your graph to predict the changes in blood glucose concentration for a person who ate the same meal, but who did not have diabetes. [3 marks]

01.3 Explain what causes the difference in the blood glucose concentrations of someone with type 1 diabetes compared to someone who does not have type 1 diabetes. [2 marks]

02 Fertility can be controlled by a variety of hormonal and non-hormonal methods of contraception. **Table 2** shows the pregnancy rate for some different methods of contraception. Pregnancy rate is the percentage of women who get pregnant in the first year of use.
Figures are given for perfect use, which is under medical study, and typical use, which is general everyday use.

Table 2

Contraception method	Pregnancy rate for perfect use	Pregnancy rate for typical use
no method	85.0	85.0
condom	2.0	17.4
hormone releasing intrauterine device (IUD)	0.1	0.1

Table 3 shows some information about condoms and a hormone-releasing intrauterine device (IUD).

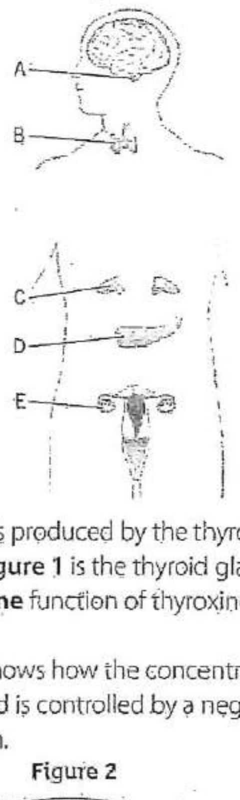
Table 3

Condom	Hormone IUD
A condom is a rubber sheath that covers the erect penis. Condoms can be bought in supermarkets.	The IUD releases a hormone similar to progesterone. It will release the hormone for about five years and then has to be replaced. It is inserted and removed by a nurse or doctor. It is usually recommended for use by women who have had a child.

Evaluate the use of condoms and hormone releasing IUDs for contraception.
You should include how each method works as well as their advantages and disadvantages. [6 marks]

03 **H** **Figure 1** shows the organs in the endocrine system.

Figure 1

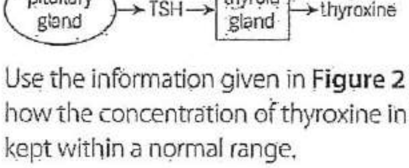


03.1 Thyroxine is produced by the thyroid gland. Which gland in **Figure 1** is the thyroid gland? [1 mark]

03.2 Describe **one** function of thyroxine in the body. [1 mark]

Figure 2 shows how the concentration of thyroxine in the blood is controlled by a negative feedback mechanism.

Figure 2



03.3 Use the information given in **Figure 2** to explain how the concentration of thyroxine in the blood is kept within a normal range. [6 marks]