Eton College King's Scholarship Examination 2015

SCIENCE 1

(60 minutes)

Candidate Number:_____

*Write your candidate number, **not your name**, in the space provided above.*

*You should attempt **ALL** the questions. Write your answers in the spaces provided. Continue on a separate sheet of paper if you need more space to complete your answer to any question.*

Allow yourself about 12 minutes for each question.

The maximum mark for each question or part of a question is shown in square brackets.

In questions involving calculations, all your working must be shown.

For examiners' use only.

1	2	3	4	5	TOTAL

1. The table below provides information about a number of compounds and should be used to help answer the questions that follow.

COMPOUND	FORMULA	SOLUBILITY IN WATER	COLOUR IN SOLUTION	COLOUR OF SOLID
calcium sulphide	CaS	(reacts with water)	-	white
barium sulphate	$BaSO_4$	insoluble	-	white
magnesium chloride	$MgCl_2$	soluble	colourless	white
iron sulphate	$FeSO_4$	soluble	green	green
magnesium sulphate	$MgSO_4$	soluble	colourless	white
barium chloride	$BaCl_2$	soluble	colourless	white
	$NaClO_3$	soluble	colourless	white

a) Suggest the name of the compound with the formula $NaClO_3$. [1]

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b) Magnesium sulphate can be prepared by adding excess magnesium powder to iron sulphate solution.

(i) What would be **seen** to happen **to the solution** during the reaction? [1]

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(ii) Explain why excess magnesium is used. [2]

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(iii) Write a word equation to represent the reaction which takes places. [2]

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(iv) What type of reaction is this? [1]

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(v) What does the reaction tell you about the reactivities of magnesium and iron? [1]

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c) When small pieces of iron are dropped into magnesium chloride solution, they very slowly become coated in a brown solid. What is this solid? [1]

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d) Describe what would be **seen** when solutions of magnesium sulphate and barium chloride are mixed. [1]

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e) Copper chloride ($CuCl_2$) can be prepared by adding excess copper oxide to hydrochloric acid. Explain why you would expect copper oxide to react with an acid. [2]

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f) Copper chloride can also be prepared by adding excess copper carbonate to hydrochloric acid. What would be **seen** to happen during this reaction, which would not be seen in the reaction using copper oxide? Explain your answer. [2]

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2. A chemist analysed a bottle of black ink. Some inks consist of pigments (colours) dissolved in a solvent. Others consist of *colloids* – tiny particles of *solid* pigments dispersed, but not dissolved, in a liquid. These particles are so small that they do not settle out at the bottom of the liquid, and they are too small to be removed by filtration. The ink investigated by the chemist contains only pigments dissolved in water.

a) State a **chemical** test, and its result, which would show that the ink contains water. [2]

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b) Name the method the chemist would use to obtain a sample of pure water from the ink. [1]

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c) Other than by using the technique named in part (b) above, suggest how the chemist might show that the ink contains dissolved pigments, rather than being a colloid. [2]

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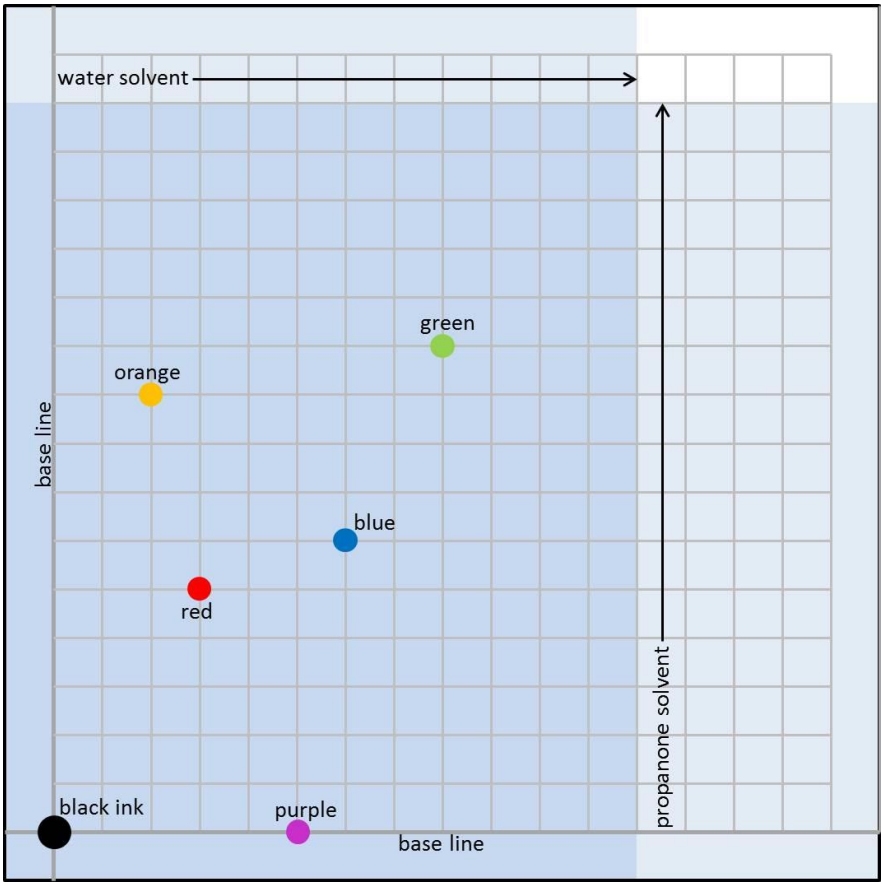
A single sample of the black ink was placed near the bottom right corner of a piece of filter paper, on a base line, as shown. The bottom edge of the paper was suspended in a trough of water, and the water was allowed to soak up the paper to a height of 12 cm above the base line. The paper was then removed from the water, rotated 90° clockwise, and then suspended in a different solvent (propanone). This was allowed to soak up the paper to a height of 15 cm above the base line, as shown. The black ink separated into different coloured pigments, as shown.
The scale in the diagram is 1 square = 1 cm.



d) Name the technique used by the chemist. [1]

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e) Explain why the purple spot has not moved upwards from the base line. [1]

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The retardation factor (R_f) of a particular substance in a particular solvent can be calculated using the formula:

$$R_f = \frac{distance\ travelled\ by\ the\ centre\ of\ the\ spot\ from\ the\ base\ line}{distance\ travelled\ by\ the\ solvent\ from\ the\ base\ line}$$

f) Calculate the R_f value for the red compound in the water solvent. **Show your working**. [2]

g) Which colour has the same R_f value in both solvents? [1]

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h) List all of the colours which have a lower R_f value in water than in propanone. [2]

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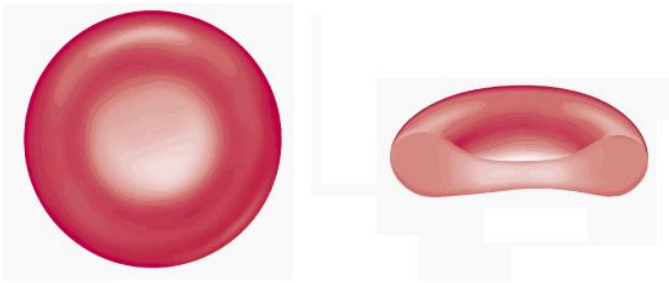
i) The black ink contained a sixth compound, X. The R_f value for X in water is 0.33, and the R_f value for X in propanone is 0.8. Use the letter X on the diagram to show the position on the paper in which the spot of compound X would be found. [2]

3. The pictures below show two different views of a red blood cell. The image on the left shows a whole red blood cell viewed from above, the image on the right shows a side view of a red blood cell that has been sliced in half.



a) What is the role of a red blood cell? [2]

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b) Using the diagram above, and your own knowledge, describe how red blood cells are adapted to their function. [3]

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Differences in red blood cells give rise to different blood groups in humans. Humans can be either blood group A, B, AB or O. All individuals inherit one blood group gene from their father, and one blood group gene from their mother. The particular combination that they inherit determines their blood group, as shown in the table below:

Gene combination	Resulting blood group
A + A	A
A + O	A
B + B	B
B + O	B
A + B	AB
O + O	O

c) Describe the role of genes in cells. [1]

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d) Explain why the variation seen in human blood groups is described as discontinuous. [2]

When an individual sexually reproduces, it is random as to which of his/her two blood group genes are inherited. For example, a man with blood group AB has a 50% chance of passing on gene A to his offspring and a 50% chance of passing on gene B.

e) A woman with blood group A has a son who is also blood group A. Two men claim to be the boy's biological father. One man is blood group A, and the other man is blood group B. Using the information provided above, is it possible to determine which man is the boy's biological father? Explain your answer. [3]

f) A couple have a daughter with blood group O. The mother is blood group B, and the father is blood group A. Calculate the probability that this couple's next child will also be a girl with blood group O. Show clearly how you arrived at your answer. [3]

4. This question is about the way electrons move through a metal and transfer energy to it. The structure of a metal is a rigid lattice (framework) of positive ions which contains freely moving electrons. If a voltage exists across the metal the free electrons flow through the lattice, forming an electric current.

a) What is the SI unit of electric current? [1]

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b) Name a component which could be used to provide a voltage. [1]

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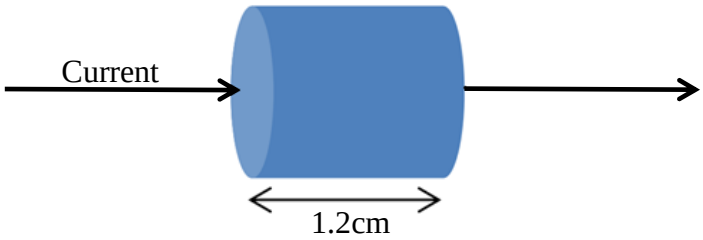
Here is a piece of copper with current flowing through it.



At any instance in time, the piece of copper contains 4.3×10^{21} free electrons. It takes two minutes for all of them to flow through the piece of copper.

c) Calculate the speed of each electron as it flows through the piece of copper, assuming they all travel at the same speed. [1]

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d) In fact, the speed of electrons increases uniformly between collisions with the lattice ions. The electrons lose speed and energy during each collision. Making the assumption that the electrons lose **all** of their speed and energy at each collision, what is their maximum speed? [1]

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e) If the distance between ions in the lattice is 2.5×10^{-10}m, what is the time between collisions for each electron? [1]

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_____

f) Sketch a speed-time graph for the motion of an electron including **at least three** collisions. Include values wherever possible. [4]

g) The free electrons collectively transfer 0.001J of energy to the lattice each second. Show that the energy each electron loses during one collision is about 6×10^{-31}J. [3]

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h) Transferring energy to the lattice makes the ions vibrate more vigorously. What do you think might be the effect of this on how easily the free electrons can flow through the lattice? [2]

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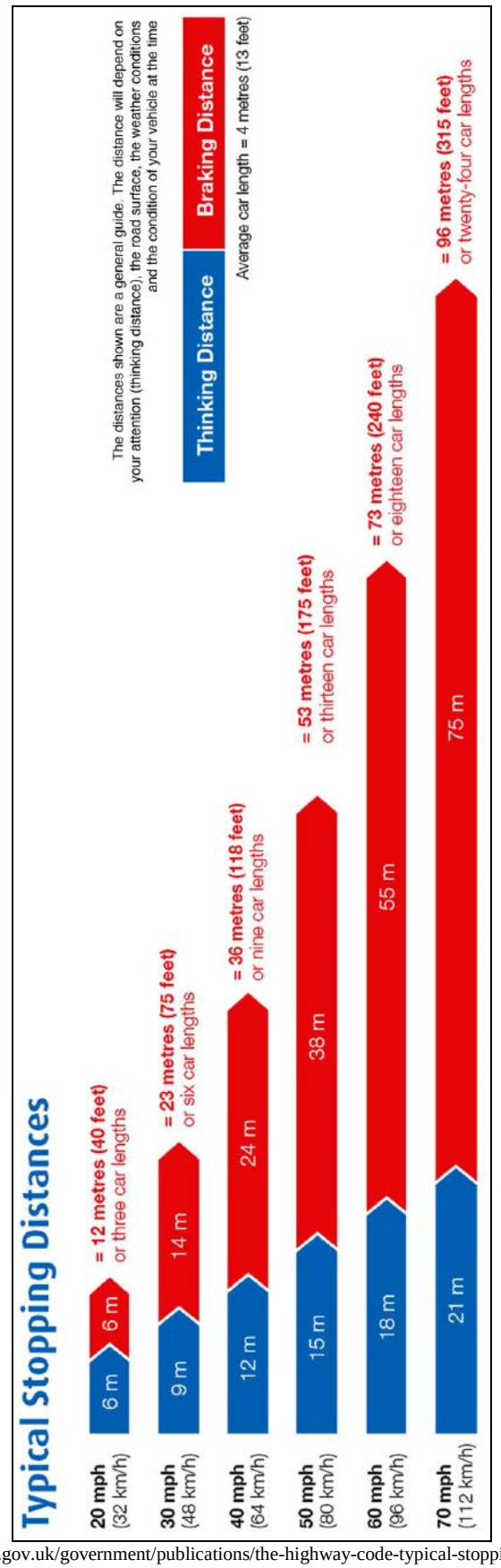
5. This question is about the total stopping distance of a car. The chart below is taken from the Highway Code.



https://www.gov.uk/government/publications/the-highway-code-typical-stopping-distances

a) What **type** of force is utilised by a car's brakes in bringing it to rest? [1]

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A car travelling at 64 km/h performs an emergency stop. A van is 65 m behind, travelling at 112 km/h, when the van driver sees the car's brake lights go on.

b) Are the two vehicles likely to collide? Justify your answer carefully. You may assume that all conditions are normal. [2]

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c) Show that 1 m/s = 3.6 km/h. [2]

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d) Use the **thinking distance** information in the Highway Code chart to determine the expected reaction time of a driver. [3]

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The total stopping distance of a car in **metres** is given by the equation:

$$total\ stopping\ distance = Av + Bv^2$$

(where v is the car's speed in kilometres per hour)

e) Use the information in the Highway Code chart to determine the values of *A* and *B*. [2]

A drunk driver in a car with worn brakes has increased total stopping distances of:

- 70 metres at 64 kilometres per hour;
- 185 metres at 112 kilometres per hour.

f) What are the new values of *A* and *B* for the drunk driver with worn brakes? [2]

g) Determine the reaction time of the drunk driver. [2]

[End of paper]