

# Chemistry 2019 v1.3

IA3 high-level annotated sample response

August 2018

## Research investigation (20%)

This sample has been compiled by the QCAA to assist and support teachers to match evidence in student responses to the characteristics described in the instrument-specific marking guide (ISMG).

### Assessment objectives

This assessment instrument is used to determine student achievement in the following objectives:

2. apply understanding of the properties and structure of organic materials or chemical synthesis and design to develop research questions
3. analyse research evidence about the properties and structure of organic materials or chemical synthesis and design
4. interpret research evidence about the properties and structure of organic materials or chemical synthesis and design
5. investigate phenomena associated with the properties and structure of organic materials or chemical synthesis and design through research
6. evaluate research processes, claims and conclusions about the properties and structure of organic materials or chemical synthesis and design
7. communicate understandings and research findings, arguments and conclusions about the properties and structure of organic materials or chemical synthesis and design.

**Note:** Objective 1 is not assessed in this instrument.

# Instrument-specific marking guide (ISMG)

## Criterion: Research and planning

### Assessment objectives

2. apply understanding of the properties and structure of organic materials or chemical synthesis and design to develop research questions
5. investigate phenomena associated with the properties and structure of organic materials or chemical synthesis and design through research

The student work has the following characteristics:	Marks
<ul style="list-style-type: none"><li>informed application of understanding of the properties and structure of organic materials or chemical synthesis and design demonstrated by a considered rationale identifying clear development of the research question from the claim</li><li>effective and efficient investigation of phenomena associated with the properties and structure of organic materials or chemical synthesis and design demonstrated by<ul style="list-style-type: none"><li>a specific and relevant research question</li><li>selection of sufficient and relevant sources.</li></ul></li></ul>	5–6
<ul style="list-style-type: none"><li>adequate application of understanding of the properties and structure of organic materials or chemical synthesis and design demonstrated by a reasonable rationale that links the research question and the claim</li><li>effective investigation of phenomena associated with the properties and structure of organic materials or chemical synthesis and design demonstrated by<ul style="list-style-type: none"><li>a relevant research question</li><li>selection of relevant sources.</li></ul></li></ul>	3–4
<ul style="list-style-type: none"><li>rudimentary application of understanding of the properties and structure of organic materials or chemical synthesis and design demonstrated by a vague or irrelevant rationale for the investigation</li><li>ineffective investigation of phenomena associated with the properties and structure of organic materials or chemical synthesis and design demonstrated by<ul style="list-style-type: none"><li>an inappropriate research question</li><li>selection of insufficient and irrelevant sources.</li></ul></li></ul>	1–2
<ul style="list-style-type: none"><li>does not satisfy any of the descriptors above.</li></ul>	0

## Criterion: Analysis and interpretation

### Assessment objectives

- analyse research evidence about the properties and structure of organic materials or chemical synthesis and design
- interpret research evidence about the properties and structure of organic materials or chemical synthesis and design

The student work has the following characteristics:	Marks
<ul style="list-style-type: none"><li>systematic and effective analysis of qualitative data and/or quantitative data within the sources about the properties and structure of organic materials or chemical synthesis and design demonstrated by<ul style="list-style-type: none"><li>the identification of sufficient and relevant evidence</li><li>thorough identification of relevant trends, patterns or relationships</li><li>thorough and appropriate identification of limitations of evidence</li></ul></li><li>insightful interpretation of research evidence about the properties and structure of organic materials or chemical synthesis and design demonstrated by justified scientific argument/s.</li></ul>	5–6
<ul style="list-style-type: none"><li>effective analysis of qualitative data and/or quantitative data within the sources about the properties and structure of organic materials or chemical synthesis and design demonstrated by<ul style="list-style-type: none"><li>the identification of relevant evidence</li><li>identification of obvious trends, patterns or relationships</li><li>basic identification of limitations of evidence</li></ul></li><li>adequate interpretation of research evidence about the properties and structure of organic materials or chemical synthesis and design demonstrated by reasonable scientific argument/s.</li></ul>	3–4
<ul style="list-style-type: none"><li>rudimentary analysis of qualitative data and/or quantitative data within the sources about the properties and structure of organic materials or chemical synthesis and design demonstrated by<ul style="list-style-type: none"><li>the identification of insufficient and irrelevant evidence</li><li>identification of incorrect or irrelevant trends, patterns or relationships</li><li>incorrect or insufficient identification of limitations of evidence</li></ul></li><li>invalid interpretation of research evidence about the properties and structure of organic materials or chemical synthesis and design demonstrated by inappropriate or irrelevant argument/s.</li></ul>	1–2
<ul style="list-style-type: none"><li>does not satisfy any of the descriptors above.</li></ul>	0

## Criterion: Conclusion and evaluation

### Assessment objectives

- interpret research evidence about the properties and structure of organic materials or chemical synthesis and design
- evaluate research processes, claims and conclusions about the properties and structure of organic materials or chemical synthesis and design

The student work has the following characteristics:	Marks
<ul style="list-style-type: none"><li>insightful interpretation of research evidence about the properties and structure of organic materials or chemical synthesis and design demonstrated by <u>justified conclusion/s linked to the research question</u></li><li>critical evaluation of the research processes, claims and conclusions about the properties and structure of organic materials or chemical synthesis and design demonstrated by<ul style="list-style-type: none"><li><u>insightful discussion of the quality of evidence</u></li><li>extrapolation of credible findings of the research to the claim</li><li><u>suggested improvements and extensions to the investigation that are considered and relevant to the claim.</u></li></ul></li></ul>	5–6
<ul style="list-style-type: none"><li>adequate interpretation of research evidence about the properties and structure of organic materials or chemical synthesis and design demonstrated by reasonable conclusion/s relevant to the research question</li><li>basic evaluation of the research processes, claims and conclusions about the properties and structure of organic materials or chemical synthesis and design demonstrated by<ul style="list-style-type: none"><li>reasonable description of the quality of evidence</li><li><u>application of relevant findings of the research to the claim</u></li><li>suggested improvements and extensions to the investigation that are relevant to the claim.</li></ul></li></ul>	3–4
<ul style="list-style-type: none"><li>invalid interpretation of research evidence about the properties and structure of organic materials or chemical synthesis and design demonstrated by inappropriate or irrelevant conclusion/s</li><li>superficial evaluation of the research processes, claims and conclusions about the properties and structure of organic materials or chemical synthesis and design demonstrated by<ul style="list-style-type: none"><li>cursory or simplistic statements about the quality of evidence</li><li>application of insufficient or inappropriate findings of the research to the claim</li><li>ineffective or irrelevant suggestions.</li></ul></li></ul>	1–2
<ul style="list-style-type: none"><li>does not satisfy any of the descriptors above.</li></ul>	0

## Criterion: Communication

### Assessment objective

7. communicate understandings and research findings, arguments and conclusions about the properties and structure of organic materials or chemical synthesis and design

The student work has the following characteristics:	Marks
<ul style="list-style-type: none"><li>• effective communication of understandings and research findings, arguments and conclusions about the properties and structure of organic materials or chemical synthesis and design demonstrated by<ul style="list-style-type: none"><li>- <u>fluent and concise use of scientific language and representations</u></li><li>- <u>appropriate use of genre conventions</u></li><li>- <u>acknowledgment of sources of information through appropriate use of referencing conventions.</u></li></ul></li></ul>	2
<ul style="list-style-type: none"><li>• adequate communication of understandings and research findings, arguments and conclusions about the properties and structure of organic materials or chemical synthesis and design demonstrated by<ul style="list-style-type: none"><li>- competent use of scientific language and representations</li><li>- use of basic genre conventions</li><li>- use of basic referencing conventions.</li></ul></li></ul>	1
<ul style="list-style-type: none"><li>• does not satisfy any of the descriptors above.</li></ul>	0

## Task

Context
<p>Investigate one of the following claims:</p> <ul style="list-style-type: none"><li>• Plastics are bad for the environment.</li><li>• Natural shampoos are better than commercial shampoos.</li><li>• Green chemistry is clean chemistry.</li></ul> <p>You may identify an alternative claim in consultation with your teacher. This claim must be related to Unit 4 subject matter.</p>
Task
<p>Gather secondary evidence related to a research question in order to evaluate the claim. Develop your research question based on a number of possible claims provided by your teacher.</p> <p>Obtain evidence by researching scientifically credible sources, such as scientific journals, books by well-credentialed scientists, and websites of governments, universities, independent research bodies or science and technology manufacturers. You must adhere to research conventions.</p>

# Sample response

Criterion	Marks allocated	Result
<b>Research and planning</b> Assessment objectives 2, 5	6	5
<b>Analysis and interpretation</b> Assessment objectives 3, 4	6	5
<b>Conclusion and evaluation</b> Assessment objectives 4, 6	6	5
<b>Communication</b> Assessment objective 7	2	2
<b>Total</b>	<b>20</b>	<b>17</b>

The annotations show the match to the instrument-specific marking guide (ISMG) performance-level descriptors.

**Key:**      Research and planning      Analysis and interpretation      Conclusion and evaluation      Communication

**Note:** Colour shadings show the characteristics evident in the response for each criterion.

<p><b>Research and planning [3–4]</b></p> <p>a reasonable rationale that links the research question and the claim</p> <p>The rationale shows that the research question is connected to the claim. However, the process by which the research question has been developed from the claim is not clearly shown.</p>	<h2 style="text-align: center;">Are natural shampoos better cleaners than synthetic shampoos based on surface tension, wetting time, solid content, detergency and foaming ability?</h2> <h3>Claim</h3> <p>Natural shampoos are better than synthetic shampoos.</p> <h3>Rationale</h3> <p>Body care products company Australian Biologika market their shampoo and conditioners as ‘caring for yourself ... without the dangers of harmful chemicals ... thus improving your health...’. (Buy Organics Online n.d.) The chemicals in the Biologika shampoo are claimed to be all natural and from organic sources. This would suggest that shampoos containing synthetic chemicals are in fact more toxic or damaging to the body. The most common reaction that people have to shampoos and other cosmetics is contact dermatitis (Seidu 2016). This can result in redness of the skin, scaly and itchy patches, burning sensations, as well as other</p>
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**Research and planning [5–6]**

**a specific and relevant research question**

The research question is clearly defined and developed from the claim. The response clearly states the variables to be investigated.

The research question is connected to the rationale and the topic of chemical synthesis and design.

**selection of sufficient and relevant sources**

Sources are scientific and provide enough evidence for the development of a scientific argument that responds to the research question.

**Research and planning [3–4]**

**a reasonable rationale that links the research question and the claim**

Scientific literature shows the link between the research question and the claim.

effects. Several sources (SLS Free n.d.) claim that the irritation is due to the presence of sodium lauryl sulfate, a surfactant found in shampoos. It is the surfactant that cleans the hair. Natural surfactants are found in yucca extract, soapwort and Quillaja bark extract.

Ultimately, a shampoo needs to clean dirty hair; however, this is only one aspect to consider when deciding which shampoo to purchase. To determine whether a shampoo is effective at cleaning hair, it is essential to understand how the surfactants in a shampoo clean the hair and alter the properties of water to allow for cleaning to occur.

## The research question

Are natural shampoos better cleaners than synthetic shampoos based on the properties of surface tension, wetting time, solid content, detergency and foaming ability?

This review will use three studies from Badi & Khan (2014), Isaiah & Karthikeyan (2015) and Mainkar & Jolly (2001) that have been undertaken to determine the effectiveness of natural versus synthetic shampoos. The results of these studies will be compiled to investigate whether natural shampoos are better cleaners than synthetic shampoos.

## Background

### How does a shampoo clean hair?

The dirt that needs to be removed is a mixture of dust, pollen and other particles that get trapped in the sebum. Sebum is a greasy substance that is produced in the sebaceous glands around the body, including the scalp, that have a role in protecting the hair and hair follicle (ThoughtCo. 2017). Approximately 41% of the 'dirt' is composed of wax esters (~26%), squalene (~12%) and free fatty acids (~16%) (Thody & Shuster 1989). It is the long, aliphatic carbon chains of these molecules that makes them insoluble in water and, therefore, unable to be simply rinsed from the hair with water.

When sodium lauryl sulfate is combined with water in dirty hair, the nonpolar aliphatic end of the molecule will dissolve in the sebum, which is also nonpolar. The hydrophilic (water-loving) end, the sulfate will form a sphere around the sebum and other non-polar molecules, forming a micelle. As the soluble, hydrophilic sulfate heads form the outer layer of the sphere and point towards the water, the micelle is now essentially water soluble. This means that the greasy substance can now be removed from the hair when rinsed with water (Cruzan 2012).

Natural surfactants will work in the same way as the sodium lauryl sulfate, forming water soluble micelles that trap the sebum droplets and remove the dirt from the hair. Other components of a shampoo include thickeners, emulsifiers and perfumes, among others; however, it is the surfactants that do the cleaning.

### Analysis and interpretation [5–6]

#### thorough and appropriate identification of limitations of evidence

The response identifies limitations of evidence that affect how well it can be used to develop a response to the research question.

#### identification of sufficient and relevant evidence

The evidence is appropriate for the purpose of responding to the research question. It is applicable and directly connected to the formation of the scientific argument.

#### thorough identification of relevant trends, patterns or relationships

The response identifies trends, patterns or relationships that are not superficial or partial. The trends, patterns, or relationships have direct bearing upon and are applicable to the formation of the scientific argument.

### Analysis and interpretation [3–4]

#### reasonable scientific argument/s

The argument is sensible. However, it is not justified.

## Analysis and interpretation

### Natural vs. synthetic shampoos — a review of results

The ability of a shampoo to clean hair can be judged on the surface tension, the amount of solid material present, the wetting time and the foam production. Three papers by Badi and Khan, Isaiah and Karthikeyan, and Mainkar and Jolly have reported the findings of tests between natural shampoos and commercially produced synthetic shampoos for several factors; however, not all factors were tested by all three reviews. The summarised relevant results to determine whether natural shampoos are better cleaners are presented in Table 1. The natural shampoos have been shaded for clarity.

Table 1: Comparison of natural shampoos (shaded) and synthetic shampoos

	(Badi 2014)			(Isaiah 2015)		(Mainkar 2001)	
	Formulated Shampoo	Dove	Herbal Essence	Ego-cert	Undisclosed synthetic shampoo	Laboratory shampoo	Average of five commercial shampoos
Surface tension (dynes/cm)	38.72	31.68	38.36	32	34	37.1	32.8–37.7
Wetting time (sec)	187	141	157			130	159–227
Solid content (%)	22.75	25	25	25.3	26.5		
Foam description	Small dense	Small dense	Small airy			Loose open	Dense creamy
Foam height (mL)	115	92	113	165	169	158	153–168
	2% solution			1% solution			
Detergency (% sebum removal)				93	95	61.14	61.1–80.12

### Surface tension

Surface tension in water is due to the intermolecular forces (hydrogen bonding) holding the water molecules together. This creates a skin-like effect on the surface of the water. The addition of a surfactant reduces the surface tension of the water, which enables the water to penetrate a surface, increasing access of the shampoo to the sebum to facilitate its removal. A higher surface tension means a reduced ability to clean the hair. Badi et. al. had a natural formulation that had a higher surface tension, 38.72 dynes/cm, than both of the synthetic shampoos tested. The results from Manikar et. al. suggested the same, that the commercial (synthetic) shampoos were in fact better at reducing surface tension. Isaiah et. al. identified that the synthetic shampoo had a lower surface tension than Ego-cert, the natural shampoo. Only looking at surface tension from these three studies does not allow a judgement to be made about the ability of a natural shampoo to clean compared to a synthetic shampoo.



## Communication [2]

### appropriate use of genre conventions

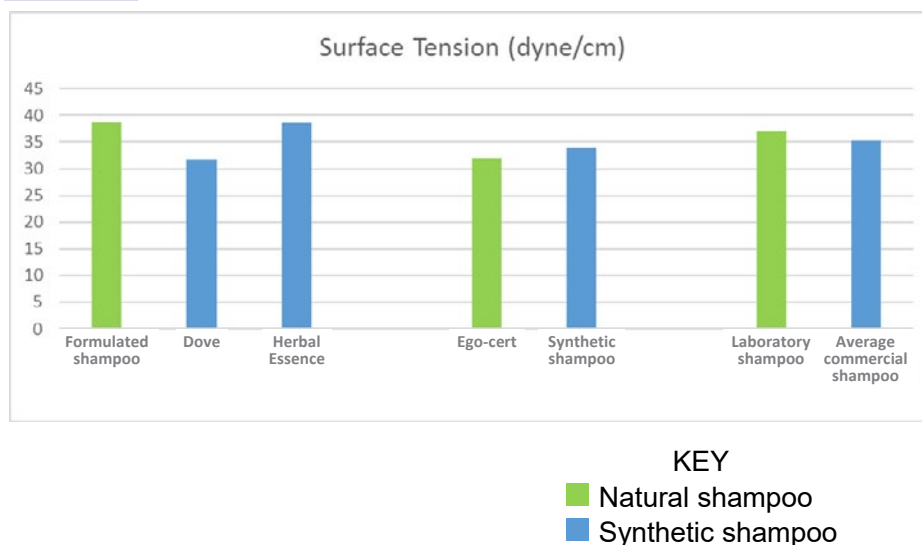
In presenting data, the response follows conventions of graph construction that fit the purpose of a research investigation.

## Analysis and interpretation [5–6]

### thorough and appropriate identification of limitations of evidence

The response identifies limitations of evidence that affect how well it can be used to develop a response to the research question.

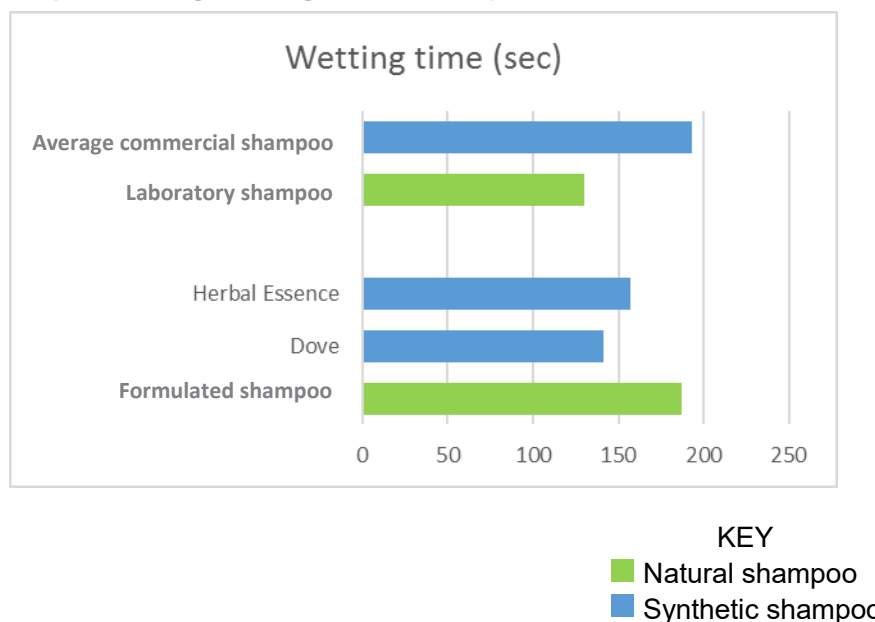
**Graph 1: Comparison of surface tensions of natural and synthetic shampoos**



## Wetting time

The wetting time is directly related to the amount of surfactant in the shampoo and consequently the surface tension of the water. The more surfactant that is present, the lower the surface tension, and the more quickly water will be absorbed into the material being cleaned — in this case, the hair. The results from Badi and Khan support this: Dove shampoo, a synthetic shampoo, with the lowest surface tension of 31.68 dynes/cm, had the quickest wetting time of 141 seconds. Mainkar and Jolly also tested wetting time, but from their research the relationship between wetting time and surface tension is inconclusive. This is primarily due to the combining of results of the commercial (synthetic) shampoos.

**Graph 2: Average wetting time for shampoos**



**Analysis and interpretation [5–6]**

**thorough and appropriate identification of limitations of evidence**

The response identifies limitations of the evidence that are not superficial or partial. The limitations are suitable for determining the reliability of the evidence in responding to the research question.

**Analysis and interpretation [3–4]**

**reasonable scientific argument/s**

The scientific argument is appropriate given the evidence. However, it is not justified as the argument has not been supported with evidence.

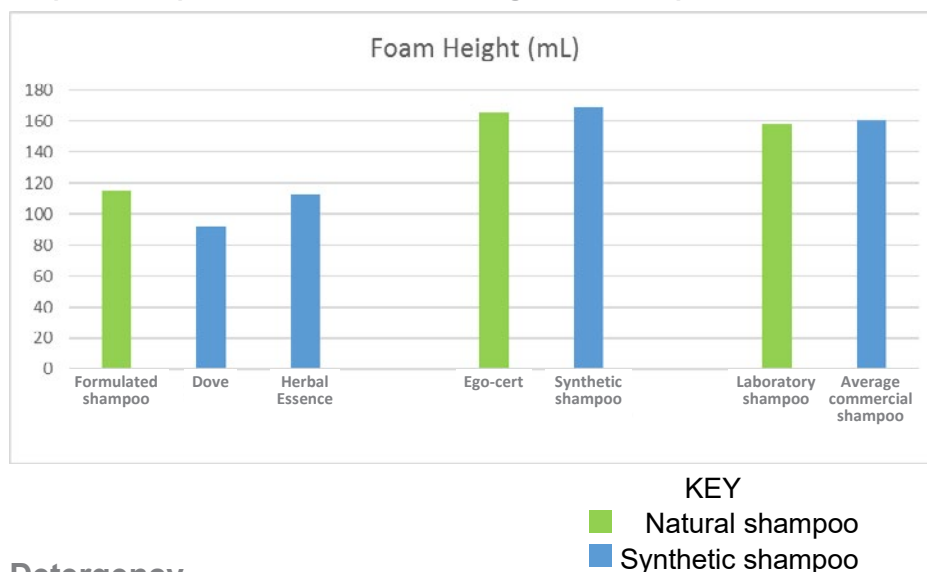
## Solid content

The optimal solid content for a shampoo is between 20–30% (Badi & Khan 2014). If it is too low, a shampoo will be too watery and wash away too quickly, leaving sebum in the hair; too high, and the shampoo will not rinse easily from the hair. All shampoos in the two studies that looked at solid content fell between these limits.

## Foaming ability

Many think that a good shampoo is one that foams well (Draelos 2010). The ability of a shampoo to foam is not just based on the contents of the shampoo, but also the hardness of the water the shampoo is being used with. The foaming of a shampoo influences its ability to be spread through the hair, but it does not act to clean the hair. A higher foam column means more foam and, therefore, an increased distribution of shampoo through the hair. The three studies used different concentrations of shampoo in determining foam height and potentially had water of different hardness, but were consistent within their own studies. Again, the results are inconclusive as to whether the natural shampoo foamed more than the synthetic shampoo. Badi and Khan had a foam height slightly higher with the natural shampoo, Isaiah and Karthikeyan slightly higher with the synthetic shampoo. Again, there is no clarity of results in Mainkar and Jolly's study due to the grouping of synthetic detergents, the natural shampoo sitting within the range produced by the synthetic shampoos.

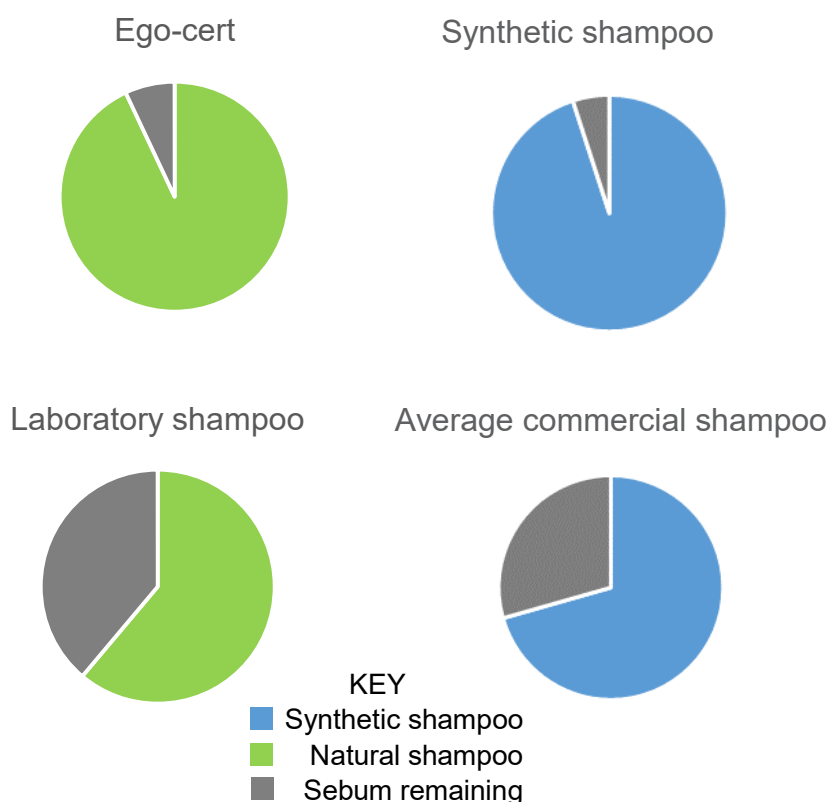
Graph 3: Comparison of foam column heights for shampoos



## Detergency

Detergency has been measured as the percentage of sebum removed from the hair when washed with a solution of the shampoo. Isaiah and Karthikeyan used a 1% solution; the concentration of solution was not given in the other paper. In both studies, the performance of the synthetic shampoo was better than the natural shampoo; however, the difference in detergency is quite small and, therefore, not enough to make a definitive statement about the cleaning ability of the shampoo.

Graph 4: Comparison of sebum removed by different shampoos



#### Conclusion and evaluation [5–6]

##### insightful discussion of the quality of evidence

The discussion shows understanding of the features of the evidence that affect its ability to be used to respond to the research question.

##### justified conclusion/s linked to the research question

The response uses sound reasoning and valid and reliable evidence to support conclusions that directly respond to the research question.

## Conclusion and evaluation

### Reviewing the literature sources

Three studies were chosen in an attempt to ensure consistency of results about the cleaning properties of natural and synthetic shampoos. Badi and Khan (2014) and Isaiah and Karthikeyan (2015) contained detailed experimental procedures that could be replicated. However, these two papers used different techniques and concentrations of shampoo when conducting the tests. This limits the ability to compare the results of the two studies. Realistically, only their conclusions can be used. Mainkar and Jolly's paper (2001) contains no detail of the preparation of solution, the concentrations of solution or the methods used to determine the results. Mainkar and Jolly also only reported the synthetic shampoo results grouped and averaged. This does not provide clarity in the comparison between natural and synthetic shampoos. This paper, therefore, does not add value to the discussion on the comparison of shampoos. All papers were published in journals, so their results are deemed to be reliable. It is the lack of consistent results in the three papers that leads to no decisive result about the cleaning ability of natural and synthetic shampoos.

### Conclusion and evaluation [3–4]

#### application of relevant findings of the research to the claim

The findings have been applied to the claim. However, the findings suggest that the claim is false, i.e. natural shampoos are not better than synthetics.

### Conclusion and evaluation [5–6]

#### suggested improvements and extensions to the investigation that are considered and relevant to the claim

The improvements address the limitations associated with the evidence. The extensions identify modifications that would complement the findings of the investigation and have the potential to provide new evidence that could be used to evaluate the claim further.

### Communication [2]

#### fluent and concise use of scientific language and representations

The response is easily understood, avoids unnecessary repetition and meets the required length.

## Overall results

The three studies used to determine whether a natural or synthetic shampoo is better at cleaning hair have not led to any conclusive results. The characteristics used to determine whether a shampoo cleans better were limited to the surface tension of the water when the shampoo was added, wetting time, foaming ability, solid content and detergency. In all three studies, the natural shampoo performed better in some characteristics, while the synthetic shampoo in other characteristics. Therefore, the review of the studies done into cleaning ability does not support or refute the claim that natural shampoos are better cleaners than synthetic shampoos.

## Further investigations required

To truly investigate whether natural shampoos are better than synthetic shampoos in terms of surface tension, wetting time, solid content, foaming ability and detergency, further testing would need to be carried out. This testing would need to involve a larger sample of both natural and synthetic shampoos. The amount of shampoo would need to remain constant in all testing and be similar to the quantity of shampoo used when washing hair, and the hardness of the water would also need to be constant. The effect of water hardness on cleaning ability could also be investigated. Two of the studies used laboratory-formulated shampoos rather than commercially available formulations. For the results to be relevant to consumers, the shampoos investigated should be readily available.

The question of whether natural shampoos are better than synthetic shampoos is not just dependent on cleaning ability. Shampoos have reportedly been linked to skin reactions. To investigate this, patch testing of a variety of shampoos, both synthetic and natural, would need to occur on a sample of population that is representative of the whole. The environmental impact of shampoo, both short and long term, would also need to be considered in evaluating the claim that natural shampoos are better than synthetic shampoos. Ultimately, the best shampoo will be the best cleaner, have the least environmental impact and not react with a user's skin.

Word count: 1805

## Communication [2]

### acknowledgment of sources of information through appropriate use of referencing conventions

Sources of information are acknowledged using a referencing style that is suitable for the purpose of the essay.

## Reference list

- Badi, AK & Khan, SA 2014, 'Formulation, evaluation and comparison of the herbal shampoo with the commercial shampoos', *Beni-Suef University Journal of Basic and Applied Sciences*, vol. 3, no. 4, pp. 301–305, [www.doi.org/10.1016/j.bjbas.2014.11.005](http://www.doi.org/10.1016/j.bjbas.2014.11.005).
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- Thody AJ & Shuster, S 1989, 'Control and function of sebaceous glands', *Physiological Reviews*, vol. 69, no. 2, pp. 383–416, [www.ncbi.nlm.nih.gov/pubmed/2648418](http://www.ncbi.nlm.nih.gov/pubmed/2648418).
- ThoughtCo. 2017, 'How shampoo works', [www.chemistry.about.com/od/howcleanerswork/a/How-Shampoo-Works.htm](http://www.chemistry.about.com/od/howcleanerswork/a/How-Shampoo-Works.htm).