

Oxford Resources for IB

Biology – 2023 Edition

Answers

Topic A1 – Molecules

Page 5 Applying techniques: Demonstrating the strength of the hydrogen bond.

- Friction will vary from syringe to syringe but the plunger should start moving downwards with force of about 2 N.
- Expected force required is less than that exerted by a kilogram of masses hanging from the barrel; friction should not be relevant to final volume (as long as the weight is sufficient to overcome the frictional force so the syringe moves)

pressure \times volume = constant (at constant temperature and constant number of gas molecules – Boyle's Law)

$$p_1 \times V_1 = p_2 \times V_2 \text{ so}$$

$$V_2 = \frac{p_1 \times V_1}{p_2}$$

$$p_1 = 1 \text{ atmosphere} = 100\,000 \text{ Pa}; V_1 = 5 \text{ mL};$$

$$p_2 = 1 \text{ atmosphere} - (\text{pressure due to weight})$$

$$\text{negative pressure due to the weight} = \frac{\text{force}}{\text{area}} = \frac{\text{mass} \times g}{\pi \times r^2} = \frac{9.8 \text{ N}}{\pi \times (7.5 \text{ mm})^2} = 0.055 \text{ N mm}^{-2} = 55\,000 \text{ Pa}$$

$$p_2 = 100 \text{ kPa} - 55 \text{ kPa} = 45 \text{ kPa}$$

$$V_2 = \frac{p_1 \times V_1}{p_2} = \frac{100 \text{ kPa} \times 5 \text{ mL}}{45 \text{ kPa}} = 11 \text{ mL}$$

- Volume can only increase if water separates to create new areas of water surface area with water vapour between. Area = $2 \times \pi \times 7.5 \text{ mm} \times 7.5 \text{ mm} = 3.5 \times 10^{-4} \text{ m}^2$

Surface energy of water (which is the same as surface tension but expressed as energy area rather than force length) = 72 mJ m^{-1}

So energy required to create new surfaces is $3.5 \times 10^{-4} \times 72 \times 10^{-3} = 2.5 \times 10^{-5} \text{ J}$

By conservation of energy, this can be equated to work required to move the syringe over a distance sufficient to separate the two water surfaces (work = force \times distance). A rough estimate of the distance at which the water surfaces would be separate is the length of a hydrogen bond = 0.35 nm therefore:

$$\text{force} = \frac{2.5 \times 10^{-5}}{0.35 \times 10^{-9}} = 70\,000 \text{ N}$$

Mass required is around 7000 g. In practice, a break would occur with less mass between the water surface and the inner surface of the syringe because the attractions are less strong. Also it is unlikely that all parts of the apparatus would withstand a mass of 7 kg so there is likely to be a failure with less weight (e.g. an air leak through the gate clip). Nevertheless, more than 1 kg of mass should hang from the plunger and it is impressive that the hydrogen bonds in a 10 mL syringe can potentially withstand 7 kg of mass before they break.

Ib Biology 2paper Answers

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Table of Contents Ib Biology 2paper Answers

1. Understanding the eBook Ib Biology 2paper Answers
 - The Rise of Digital Reading Ib Biology 2paper Answers
 - Advantages of eBooks Over Traditional Books
2. Identifying Ib Biology 2paper Answers
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Ib Biology 2paper Answers
 - User-Friendly Interface
4. Exploring eBook Recommendations from Ib Biology 2paper Answers
 - Personalized Recommendations
 - Ib Biology 2paper Answers User Reviews and Ratings
 - Ib Biology 2paper Answers and Bestseller Lists
5. Accessing Ib Biology 2paper Answers Free and Paid eBooks
 - Ib Biology 2paper Answers Public Domain eBooks
 - Ib Biology 2paper Answers eBook Subscription Services
 - Ib Biology 2paper Answers Budget-Friendly Options
6. Navigating Ib Biology 2paper Answers eBook Formats

- ePub, PDF, MOBI, and More
- Ib Biology 2paper Answers Compatibility with Devices
- Ib Biology 2paper Answers Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Ib Biology 2paper Answers
 - Highlighting and Note-Taking Ib Biology 2paper Answers
 - Interactive Elements Ib Biology 2paper Answers
- 8. Staying Engaged with Ib Biology 2paper Answers
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Ib Biology 2paper Answers
- 9. Balancing eBooks and Physical Books Ib Biology 2paper Answers
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Ib Biology 2paper Answers
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Ib Biology 2paper Answers
 - Setting Reading Goals Ib Biology 2paper Answers
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Ib Biology 2paper Answers
 - Fact-Checking eBook Content of Ib Biology 2paper Answers
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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