Development of DIGaKiT: identifying students' alternative conceptions by Rasch analysis model

by Mutiara Arieny

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ABSTRACT

Alternative conceptions become obstacles in physics. However, it is difficult to find instruments that can identify students' alternative conceptions, especially in gases kinetic theory (DIGaKiT). The purpose of this research was to development of diagnostic instrument of DIGaKiT in identifying students' alternative conceptions by Rasch analysis model. The research method used the defining, designing, developing, and disseminating (4D). The samples are 31 students (12 male students and 19 female students, their ages were typically 16 years old) at one of the senior high schools at Belitung. Rasch analysis was used to identify the validity, reliability, and distribution of students' alternative conceptions. The result is that the level of validity and reliability of the instrument is in a good category. Meanwhile, alternative conceptions of the kinetic theory of gases can be identified in all questions, and the questions with the highest alternative conceptions are questions with code Q11 (77%) and the lowest are questions with codes Q1, Q5, and Q6 (4%). Therefore, teachers must design learning processes that can reduce students' alternative conceptions of the kinetic theory of gases material.

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1. INTRODUCTION

Students do not originate in the classroom with unfilled attention, since they progress views about belongings that occur in their environs from the very initial existences of their lives to any preceding life involvement or observation, not essentially happening out of formal education. Repeatedly, students' ideas are dissimilar from acknowledged scientific knowledge that express as misconceptions, alternative structures, alternative conceptions, common-sense concepts, pre-concepts, beliefs [1]–[3]. Several claims about alternative conceptions, they are: i) students come to classroom together through a varied customary of alternative conceptions relating to ordinary substances and incidents, ii) the alternative conceptions that students convey toward classroom expurgated across oldness, capability, gender, and social borders, iii) alternative conceptions are obstinate and unaffected to destruction through conservative teaching approaches, iv) alternative conceptions frequently corresponding descriptions of natural phenomena obtainable thru earlier groups of experts and theorists, v) alternative conceptions take their backgrounds in a varied usual of individual involvements comprising straight observation and perception, peer civilization, and verbal, in addition to in educators' descriptions and instructional resources, vi) teachers habitually contribute toward the identical alternative conceptions as their students, vii) students' previous acquaintance interrelates through information obtainable in formal education, subsequent in a varied diversity of unintentional education consequences, and viii) instructional methods that simplify conceptual change can be actual classroom apparatuses [4]–[6].

Students' alternative conceptions contract through the usual world that is extremely unaffected to modification from wrong and correct knowledge [7]–[9]. Moreover, students' alternative conceptions supposedly are pervasive, conducted deeply, and persevere over time [10]. Alternative conception is a blockade for students to understand science for the reason that in numerous instances, alternative conceptions can hold students to build correct ideas employed as the preliminary intuition for improved learning [11]. Thus, alternative conceptions must be analyzing earlier using a diagnostic test. The diagnostic test employed numerous procedures that record repeatedly for analyzing students' alternative conceptions in science education, such as open-ended tests [12], interviews [13], multiple-choice [14], and multiple-tier tests such as two-tier test [15], three-tier test [16] and four-tier test [7]. Improvement of diagnostic tests on analyzing students' alternative conceptions shown in Figure 1. Each diagnostic test has advantages and disadvantages of each.

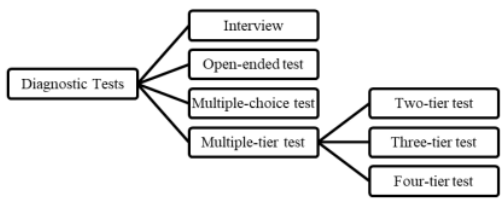

Figure 1. Improvement of diagnostic tests to analyzing students' alternative conceptions

Interviews have an important part because of their in-strength investigation and prospect of explanation to acquire comprehensive reports of a student's reasoning forms [17]–[19]. Interviewing is one of the clearest and most commonly utilized methods to discover out the information and probable students' alternative conceptions. The aim of interviewing is not to obtain responses to problems, although to discover what students believe, what is in students' way of thinking, and how students' feelings about a concept. Nevertheless, a substantial quantity of period is necessary to interview a sizeable total of the population in demand to achieve bigger generalizability. Open-ended tests provide students with the opportunity to transcribe their responses in their personal phrases and can be dispensed to greater tests. The open-ended test has numerous benefits, explicitly assisting students communicate their opinions, allowing an infinite variety for responses, decreasing in the responses offered by students [20]. However, it incomes time to examine the outcomes and counting may be a problematic, complications in taking student responses, necessitating particular skills for receiving expressive responses, roughly rejoinder responses may not be valuable, unfairness responses may happen if students do not comprehend the subject of the interrogation [17].

Towards defeat troubles in the interview and open-ended test, multiple-choice tests take place to evaluate student conception through sizable quantities of participants. The assistances of multiple-choice tests are consents investigators to variety reporting of several subjects in a comparatively quick time, adaptable and can be applied at diverse stages of tuition, unbiassed in evaluating responses and actuality consistent, and then valued in evaluating students' alternative conceptions [21]. Correspondingly, with conventional multiple-choice tests the researcher cannot differentiate accurate responses expected to accurate perceptive as of individuals owing toward inaccurate perceptive. Additionally, multiple-choice tests have numerous limitations such as predicting can cause mistakes on modifications and split consistency, selections do not afford awareness and considerate to students concerning their concepts [22].

Researchers protracted multiple-choice tests addicted to multiple-tier tests such as two-tier, three-tier and four-tier. Two-tier tests can be restrained and connected to answers correlated to alternative conceptions.

Through two-tier tests, researchers can even discovery learner responses that have not been supposed of previously [23]. Accordingly, two-tier tests might misjudge or undervalue students' scientific understanding or else miscalculate the scopes of the alternative conceptions subsequently lack of knowledge could not be strongminded through the two-tier test [24]. The restrictions stated aimed at the two-tier tests were planned to be remunerated by integrating a third tier. Through three-tier tests, alternative conceptions that are removed from a lack of knowledge and faults can be evaluated [17]. Nevertheless, three-tier tests still cannot completely distinguish the sureness selections intended for the key response from sureness selections for reasoning [7]. Consequently, may misjudge students' scores and undervalue their absence of acquaintance. However, when viewed from its strengths, the four-tier test is more effective for analyzing student alternative' conceptions. Four-tier tests can differentiate conceptions and correctly identify alternative conceptions, although it requires more time when testing [25]. The four-tier test consists of four parts, the initial tier is answering selections, the second tier is sureness grade for the initial tier, the third tier is the cause for the first tier, and the fourth tier is sureness grade for the third tier.

The analyzing of students' alternative conceptions have been done on physics concepts such as force and motion [26]–[28], geometrical optics [17], electromagnetism [29], electric circuit [30], light wave [15], and kinetic theory of gases [31]. This is caused by many physics concepts that is abstract, such as the kinetic theory of gases for the basic laws (e.g., Avogadro, Boyle, Charles, and Gay-Lussac). Avogadro's Law circumstances that the volume of a gas is comparative to the quantity of molecules of the gas atom ($V \propto n$). Boyle's Law circumstances that the volume of a gas is contrariwise comparative to the pressure when the temperature is persistent $\left(V \propto \frac{1}{P}\right)$. Charles's Law circumstances that volume is comparative to temperature when pressure is persistent ($V \propto T$). And then, Gay-Lussac's Law circumstances that pressure is comparative to temperature when the volume is persistent ($P \propto T$). Concepts about temperature, volume, pressure, and the quantity of molecules of the gas are abstract and potentially to inflict students' alternative conceptions.

Alternative conceptions on the kinetic theory of gases can be analyzed through diagnostic test in formula of four-tier test, named diagnostic instrument of Gases kinetic theory (DIGaKiT). This instrument was examined through the Rasch model. The Rasch model qualified to Danish mathematician Georg Rasch [32]. Rasch model determinations to sustenance truthful quantity. Rasch model has been experienced to develop, evaluate, and enable the intention of Rasch procedures that core to data examination and clarification of additional guarantee [33]. Hence, the goal of this study was to developed DIGaKiT grounded on the Rasch model.

2. METHOD

2.1. Sample and data collection

The samples are 31 students (12 male students and 19 female students, their ages were a typical of 16 years old) at single of senior high school at Belitung (or in English, Billiton), Indonesia. Belitung is one of the islands which is included in the western part of Indonesia as shown in Figure 2. The sample was collected by purposive sampling. The consideration practiced is students who have not yet learned about the kinetic theory of gases.

Figure 2. Map of Tanjung Pandan, Belitung (by google map)

Figure 2 shows the current research position which can be used as a reference for further research on the physics conception in Indonesia. The data was collected using the DIGaKiT. The instrument entails of 11 queries about the kinetic theory of gases in the form of four-tier test.

2.2. Research design

The research design was used defining, designing, developing, and disseminating (4D) model [34]. The design is the sequence that is carried out in this study. The details of the 4D model in this study are shown in Figure 3.

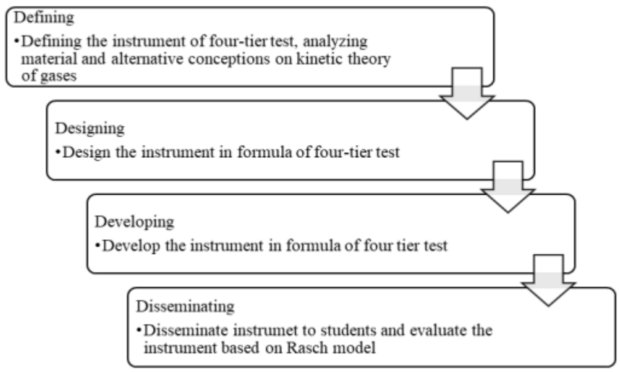

Figure 3. The research design of 4D model

2.3. Analyzing the data

Data analysis was carried out in several stages. However, before evaluating the instrument using Rasch model, the first step is categorized students' conceptions. Students' conceptions were categories as sound understanding (SU), partial understanding (PU), alternative conception (AC), no understanding (NU), and no coding (NU) as exposed in Table 1. Conception categorization is carried out to map students' conceptions with scores that will be analyzed using Rasch analysis. Rasch analysis was carried out to test validity, reliability and mapping for person and item.

Table 1. Categories and scoring of conceptions

Students' conceptions	Tier 1	Tier 2	Tier 3	Tier 4	Score
Sound understanding (SU)	Correct	Sure	Correct	Sure	3
Partial understanding (PU)	Correct	Sure	Correct	Not sure	2
	Correct	Not sure	Correct	Sure	
	Correct	Not sure	Correct	Not sure	
	Correct	Sure	Incorrect	Not sure	
	Correct	Not sure	Incorrect	Sure	
	Correct	Not sure	Incorrect	Not sure	
	Incorrect	Sure	Correct	Not sure	
	Incorrect	Not sure	Correct	Sure	
	Incorrect	Not sure	Correct	Not sure	
	Correct	Sure	Incorrect	Sure	
	Incorrect	Sure	Correct	Sure	
Alternative conception (AC)	Incorrect	Sure	Incorrect	Sure	1
No understanding (NU)	Incorrect	Sure	Incorrect	Not sure	0
	Incorrect	Not sure	Incorrect	Sure	
	Incorrect	Not sure	Incorrect	Not sure	
No coding (NC)	If not fill one or more items (tier)				

3. RESULTS AND DISCUSSION

The DIGaKiT was developed based on 4D models as follows.

3.1. Defining

On the defining stage, the four-tier test was defined. The four-tier test is a test that consists of four levels. The first level is multiple choice, the second level is sureness grade for answers at the first level, the third level is the reason for answers at the first level, and the fourth level is the sureness grade for reasons at the third level. After that, we have been analyzed material on the kinetic theory of gases for senior high school students. The data of students' alternative conceptions on the kinetic theory of gases also collected. Based on this stage, the DIGaKiT consists of 11 problems namely microscopic and macroscopic properties of gas (question number 1), the ideal gas assumption (number 2), Boyle's law (question number 3), Gay Lussac's law (questions number 4 and 5), Charles's law (question number 6), ideal gas equation (question number 7), ideal gas pressure (question number 8), ideal gas temperature (question number 9), velocity average (problem number 10), and energy equipartition theorem (question number 11).

3.2. Designing

At the designing stage, we design the DIGaKiT in a formula of four-tier test. The tier-1 is multiple-choice for answering the problem. The aim is to identify students' conceptions. The tier-2 is sureness grade for the tier-1. The aim is to identify students' beliefs about the answers given, whether they are correct and sure or wrong and sure. The tier-3 is multiple-choice of reasons for the tier-1. The aim is to further identify students' conceptions as they relate to reasons. Then the tier-4 is sureness grade intended for the tier-3. The aim is to determine the category of students' conceptions as a whole. The design shown in Figure 4.

Tier 1
Problem
A. .....
B. .....
C. .....
D. .....
E. .....
Tier 2
Sureness grade
A. Sure B. Not Sure
Tier 3
Cause
A. .....
B. .....
C. .....
D. .....
E. .....
Tier 4
Sureness grade
A. Sure B. Not Sure

Figure 4. Design of DIGaKiT

3.3. Developing

After designing the instrument, we develop 11 questions of the DIGaKiT as shown in Figure 5. At this stage, we begin to include the question components and options for tier-1 and tier-3. The intended development is realizing DIGaKiT based on the design that has been prepared in Figure 4.

3.4. Disseminating

After developing process, the DIGaKiT was implemented to 31 students for 60 minutes. Students' answers at the DIGaKiT were analyzed using categories and scoring in Table 1. The implemented process was shown in Figure 6. After applying the instrument, we evaluate the instrument created on the Rasch model. The first result is about the validity of the instrument. The outcome of validity presented in Figure 7. Figure 7 shows the unidimensionality of the developed instrument. This measure indicates whether the developed instrument is able to measure what it should measure, and in this case, it is a measure of the construct of the instrument. The value obtained for "raw variance explained by measures" from DIGaKiT is 55.0% (red box). This result is in the good category because it is above 40% [35]. Then, the outcome of reliability presented at Figure 8. Based on Figure 8, it can be seen that the result for the Cronbach Alpha of DIGaKiT is 0.92 which is included in the good category, moreover the value obtained has exceeded the limit of 0.6 [36]. After that, the distribution of person and item shows at Figure 9.

6.1 There is a pan filled with hot water and a filled bottle air with the mouth of the bottle tightly closed by balloon, as in the following picture.

Description: the orange object above a bottle is a balloon.
The bottle is then dipped in hot water, what will happen to the balloon in bottle mouth?
A. The balloon will enter the bottle.
B. The balloon will deflate.
C. The balloon will deflate and enter in a bottle.
D. The balloon will enter the bottle and inflate.
E. The balloon will inflate.
6.2 Are you sure thru your response at 6.1?
A. Sure B. Not Sure
6.3 What is your reason for answering question 6.1?
A. The air temperature in the bottle increases so the air volume increases causes air from the bottle to flow get inside the balloon.
B. The air molecules which initially unite at the moment heated to spread to everything the direction of filling an empty spot.
C. Air pressure decreases due to temperature air which increases so that the air from the outside flows into the bottle causes the balloon to come inside bottle.
D. The water in the pan evaporates and goes into in a balloon.
E. Hot water causes air in the bottle disappear.
6.4 Are you sure thru your response at 6.3?

Figure 5. Example of DIGaKiT

Figure 6. Disseminating of DIGaKiT

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TABLE 23.0 Data                                  ZOU891WS.TXT  Oct 14 2019 19:12
INPUT: 31 Person  11 Item  REPORTED: 31 Person  11 Item  4 CATS   WINSTEPS 4.4.5
--------------------------------------------------------------------------------

     Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = Item information units
                                          Eigenvalue   Observed    Expected
Total raw variance in observations     =     24.4318 100.0%         100.0%
  Raw variance explained by measures   =     13.4318  55.0%          53.6%
    Raw variance explained by persons  =      9.1576  37.5%          36.6%
    Raw Variance explained by items    =      4.2743  17.5%          17.1%
  Raw unexplained variance (total)     =     11.0000  45.0% 100.0%   46.4%
    Unexplned variance in 1st contrast =      2.7511  11.3%  25.0%
    Unexplned variance in 2nd contrast =      2.3615   9.7%  21.5%
    Unexplned variance in 3rd contrast =      1.6118   6.6%  14.7%
    Unexplned variance in 4th contrast =      1.2079   4.9%  11.0%
    Unexplned variance in 5th contrast =      1.1049   4.5%  10.0%
```

Figure 7. The result of validity grounded on the Rasch model

```
     SUMMARY OF 31 MEASURED (EXTREME AND NON-EXTREME) Person
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT         OUTFIT    |
|          SCORE     COUNT     MEASURE    S.E.      MNSQ   ZSTD   MNSQ   ZSTD |
|------------------------------------------------------------------------------|
| MEAN      23.3      11.0       1.72     .65                                  |
|  SEM       1.3        .0        .40     .06                                  |
| P.SD       6.9        .0       2.17     .35                                  |
| S.SD       7.1        .0       2.20     .36                                  |
| MAX.      33.0      11.0       6.11    1.85                                  |
| MIN.      10.0      11.0      -1.42     .40                                  |
|------------------------------------------------------------------------------|
| REAL RMSE    .77 TRUE SD    2.03  SEPARATION  2.64  Person RELIABILITY  .87 |
|MODEL RMSE    .74 TRUE SD    2.04  SEPARATION  2.74  Person RELIABILITY  .88 |
| S.E. OF Person MEAN = .40                                                    |
-------------------------------------------------------------------------------
Person RAW SCORE-TO-MEASURE CORRELATION = .97
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .92  SEM = 1.95
```

Figure 8. The result of reliability grounded on the Rasch model

Figure 9 shows the distribution of students' answers to the DIGaKiT. There are two parts shown in Figure 9 which are separated by the dotted line. The left side is the Person section (purple box) which contains a student code such as code S22, where S is the code for Student, while 22 is the student's serial number. To the right is the Item section (pink box) which contains the question code from DIGaKiT such as code Q1, where Q is the code for Question, and 1 is the serial number of the question. The distribution of student answers is also largely determined by the scoring in Table 1. The results can be identified that there are 21 students (green boxes) who have the potential to answer all the DIGaKiT. This is because its position is above all DIGaKiT questions (blue box). Of the 21 students, the ones with the highest abilities were students with codes S22 and S25, because their position was at the very top. Meanwhile, there are four students (red boxes) who potentially cannot answer the DIGaKiT questions. And of the four students, the student with the lowest ability is the student with code S08. For the quality of the DIGaKiT, questions with the highest ability to measure students are questions with code Q11, and questions with code Q5 are the lowest. Moreover, the percentage of students' alternative conceptions shown in Figure 10.

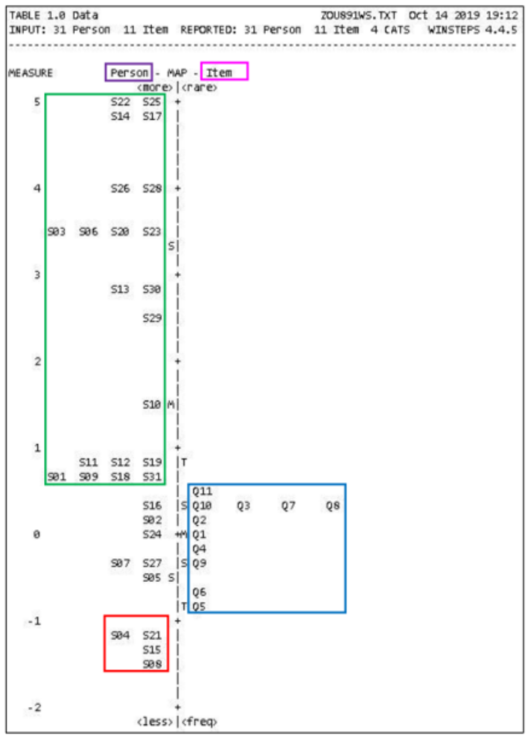

Figure 9. The distribution of person and item based on the Rasch model

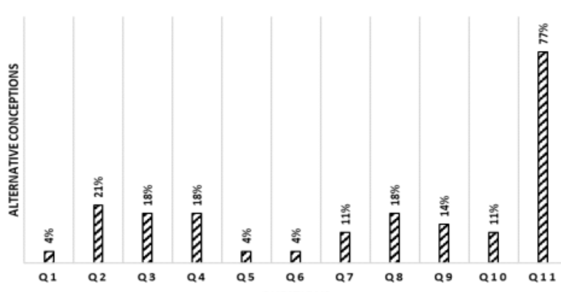

Figure 10. The percentages of students' alternative conceptions

From Figure 10, students have alternative conceptions for all questions. The largest percentage of alternative conceptions is in number 11 (Q11) about the energy equipartition theorem. The smallest percentage of alternative conceptions is in Q1, Q5 and Q6. The other students' alternative conceptions were shown in Table 2.

The DIGaKiT has been developed using the 4D model through the stages of defining, designing, developing and disseminating. At the end of the stage, the DIGaKiT was analyzed through Rasch model for validity and reliability. In the Rasch model, an acceptable dimensionality (validity) strongminded via raw variance explained by measures which ought to be further than 40% [37]. This distribution was also carried out by several researchers in identifying the distribution of student conceptions or alternative conceptions [15], [38], [39].

Students' alternative conceptions on Q11 is "the energy in a gas varies depending on the rate of reaction of the gas, and energy in a gas depends on the type of gas and does not depend on the temperature of the gas". This is likewise one of the explanations why Q11 is the most problematic problem for students to answer. In accordance with [40], students have an alternative conception of the energy equipartition theorem "the energy in a gas is contrariwise comparative to the temperature of the gas". Overall, students have an alternative conception of the kinetic theory of gas by 19%. This happens because the concept is abstract and difficult to find in everyday life. Alternative conceptions are the misperceptions that students might have owing to abstract countryside [13]. Educators will have more trouble in explanation abstract concepts because there are no physical instances in the everyday existence of the students [41].

In conclusion, students' alternative conceptions have been analyzed using the DIGaKiT at single of senior high school in Belitung, Indonesia. The DIGaKiT that in form of the four-tier test was valid and reliable to practice for analyzed students' alternative conceptions on the kinetic theory of gases. Educators must be analyzed students' alternative conceptions before learning and practice the accurate method to minimalized alternative conceptions after the learning process.

Table 2. Students' alternative conceptions on the kinetic theory of gases

No.	Sub material	Students' alternative conceptions
1.	Microscopic and macroscopic properties of gases	▪ Macroscopic properties of gas describe the behavior of each gas molecule.
2.	The ideal gas assumption	▪ Gas molecules do not meet Newton's laws of motion.
3.	Boyle's law	▪ Pressure and volume relationship graphs for five different gas systems are not sorted according to the temperature of each system. ▪ A graph of pressure and volume relationship graphs for five different gas systems starting from the higher system temperature (the deepest curved line) to the lower system temperature (the outer curved line).
4.	Charles's law	▪ Increased gas temperature causes the air volume to decrease. ▪ The volume is contrariwise comparative to gas temperature. ▪ The temperature of the gas does not affect the volume of the gas due to persistent pressure.
5.	Gay-Lussac's law	▪ Gas temperature is inversely comparative to gas pressure. ▪ There is no change in gas pressure even though the temperature of the gas is decreasing.
6.	Gas pressure in a confined space	▪ The amount of gas pressure in an enclosed space is not influenced by the volume of an enclosed space. ▪ The quantity of gas pressure is straight comparative toward the volume of closed space.
7.	The average effective velocity of an ideal gas	▪ The effective velocity of the gas is only pretentious thru the molar mass of the gas. ▪ The average effective speed of a gas is only pretentious thru the temperature of the gas.
8.	Kinetic energy of ideal gases	▪ Kinetic energy of ideal gases is straight relative to the pressure of the gas so that the kinetic energy of the temperature is curved upward.

4. CONCLUSION

This research developed DIGaKiT to identify students' alternative conceptions. Based on the Rasch analysis, it was identified that the level of validity and reliability of the instrument is in a good category. For validity, it is at a score of 55.0%, which in the Rasch modeling is a good value because it is above 40%. Reliability is at a value of 0.92. Meanwhile, alternative conceptions of the kinetic theory of gases can be identified in all questions, and the questions with the highest alternative conceptions are questions with code Q11 (77%) and the lowest are questions with codes Q1, Q5, and Q6 (4%). Thus, it can be said that the DIGaKiT can identify conceptual alternatives to the kinetic theory of gases.

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