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ABSTRACT

Most high school chemistry curricula contain a unit on gas volume and a unit on the particulate nature of matter. The existence and persistence of adolescent preconceptions about the material nature of gases is an important factor to be considered in the teaching of principles or theories related to gases. The purpose of the study reported in this paper was to investigate the development of the concept of gas volume in junior high, senior high, and university Taiwanese students (N=1,029). Two tests, the group demonstration test of the conception related to gas volume (CFB2AB), and the particulate nature of gas (CFF) test, were administered at the end of the teaching unit concerning gas. Results indicate that though students had studied the principles related to gas volume, the misconceptions they held became apparent when they encountered chemistry problems. The thinking modes of students' answers and reasoning about these kinds of questions were also analyzed in this study. (JRH)

STUDENTS' CONCEPTUAL REPRESENTATIONS OF GAS VOLUME IN RELATION TO PARTICULATE MODEL OF MATTER

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Most high school chemistry curricula contain a unit of gas volume and a unit of particulate nature about matter. Students have learned the concepts that matter is composed of particles, and that the state of matter is explained according to the arrangement of these particles. In literature, it has shown that the existence and persistence of adolescents' preconceptions about the particulate nature of gases is an important factor, when we considered the teaching of the principles or theories related to gases. The purposes of this study were to find out how the concept of gas volume was developed in Taiwanese students : (1) Do the students, at different grades, following the instruction of the topic of particulate model of gas, understand the substantial nature of the volume of gases ? (2) Can they use the scientific model about particles to describe the situations of the volume of any pure gas or the mixture of two different kinds of gases which are contained in the same vessel ? (3) What are the patterns of the students' responses on the volume of a single gas or the mixture of two different gases through particulate theory of matter ? Totally there were 1029 students as the subjects. The main findings indicated that though the students had studied the conception related to gas volume, they still hold some of the misconceptions when they encountered such problems. The thinking modes of students' answers and reasoning about these kinds of questions were also analyzed in this study.

Introduction

In recent years, many researches have dealt with the content of students reasoning in science, and a number of studies revealed that students have specific conceptions about science concepts , that are different from the orthodox concepts in science teaching (Hwang & Huang, 1983; Comber, 1983; Hwang, Hung, & Huang, 1987; Nurrenbern & Pickering, 1987; Furio Mas & Perez, 1987; Stavy, 1988; Sumfleth, 1988; Abraham, et. al., 1992; Sawrey, 1990; Stavy, 1990 ; Nakhleh, 1992; Niaz, 1992; Slone & Bokhurst, 1992; Griffiths & Preston, 1992).

Most high school chemistry curricila contain a unit on the gas volume and a unit on the particulate nature of matter. Students have learned the concept that matter is composed of particles, and the state of matter is explained according to the arrangement of these particles. Therefore, we assume that the majority of the secondary school students in Taiwan have some understanding of the scientific model about particulate nature of matter.

In the research group of Abrah... ...92), they found that even the concepts of chemistry were already taught by school teachers, the students still hold some of the misconceptions of chemical concepts. According to Stavy (1990) reaearch findings that grade four and grade five students only could understand the solid state of matter but not gaseous or liquid state. The students percepted the matter as a continuous medium, rather than as an aggregation of particles. Therefore it could be the reasons for students to have misconcepton of gases. In other worlds, even though they have learned it in school, the particulate theory does not become useful for most of the students. In Sumfleth (1988) research, he found that to teach the term knowledge was not enough in school. It should emphasize the relationships and links on the new knowledge and the preconception hold by the students. Nakhleh (1992) concluded that the reasons, why some students don learn chemistry, was that students did not well construct their own chemistry concepts at the beginning of learning chemistry. Sawrey (1990) compared the relationship between the problem solving and concept learning, and found that the ability to solve problem was better to understanding molecular concepts. Pickering (1990) had a further study on concept learning versus problem ssolving, and found most of the freshman of Princeton University had the misconception about the conceptual gas problem. Gruffiths and Preston (1992) interviewed grade 12 students, and observed 52 misconceptons relating to foundamental characteristics of atoms and molecules. Among those 52 categories, 5 misconceptions hold to half of the students in the sample . Many studentrs also hold a static rather than kinetic conception of the particulate model of matter. Nurrenbem and Pickering (1987) found that the conceptual problem was much easier than the traditional problems for freshmem in the university. In Mas and Perez (1987) research results, only 20% of English pupils aged 15 could correctly use the kinetic theory of geses in the interpretation of ordinary phenomena. In 1985, Hwang and Huang had a research on students misconception of air through particulate nature and kinetic behaviors, and found most high school students and college nonscience students did not have the particulate model of air. This is the reason why the students can not correctly learn the related science concepts.

In view of those findings, it have shown in those research that the existence and persistence of adolescents preconceptions about the material nature of gases is an important factor to be considered in the teaching of the principles or theories of conceptions related to gases. The purpose of this study was to find out how the gas volume develops in Taiwanese students. The research questions concentrated on the following points:

1. Do the students, at different grades, following the instruction of the topic of particulate model of gas, understand the substantial nature of the volume of gases?
2. Can they use the scientific model about particles to describe the situations of the vulume of any pure gas or the mixture of two different kinds of gases which are contained in the same vessel?

3. What are the patterns of the students' responses on the volume of a single gas or the mixture of two different gases through particulate theory of matter?

Methodology

Samples

Students from three school levels were used for both of the two tests (CFB2AB and CFF). There were junior high school students (grade range 8-9), senior high school students (grade range 9-12), and university students (grade range 13-15) . Totally the subjects who took the CFB2AB test consisted of 395 students in Taiwan. For the CFF task, totally there were 634 students , who took the test (Table 1). All students for these two instruments were tested after they had studied the topic of gas phase. For comparison, some of the university students were also selected as the sample. Among these subjects, some students were interviewed independently while being shown materials and process of demonstration test.

Instruments

The group demonstration tests of the conception related to gas volume (CFB2AB

Table 1 The Samples

Instrument		JUN	SEN	UNI	TOTAL
CFF	F	261	10	59	330
	M	176	71	57	304
	TOTAL	437	81	116	634
CFB2AB	F	59	109	56	224
	M	43	67	61	171
	TOTAL	102	176	117	395

), and particulate nature of gas (CFF), which were constructed by the author (B. T. Hwang), were used for the data collection. These tests were administered at the end of the teaching unit concerning gas.

Results and Dicussions

Though the students had studied the conception related to gas volume, they still hold some of the misconceptions when they encountered such problems. The answers and reasonings of students about these kinds of questions can be analyzed as follow.

ITEM B1-1: THE VOLUME OF HYDROGEN GAS IN A CONTAINER WITH A VOLUME OF 1-LITER

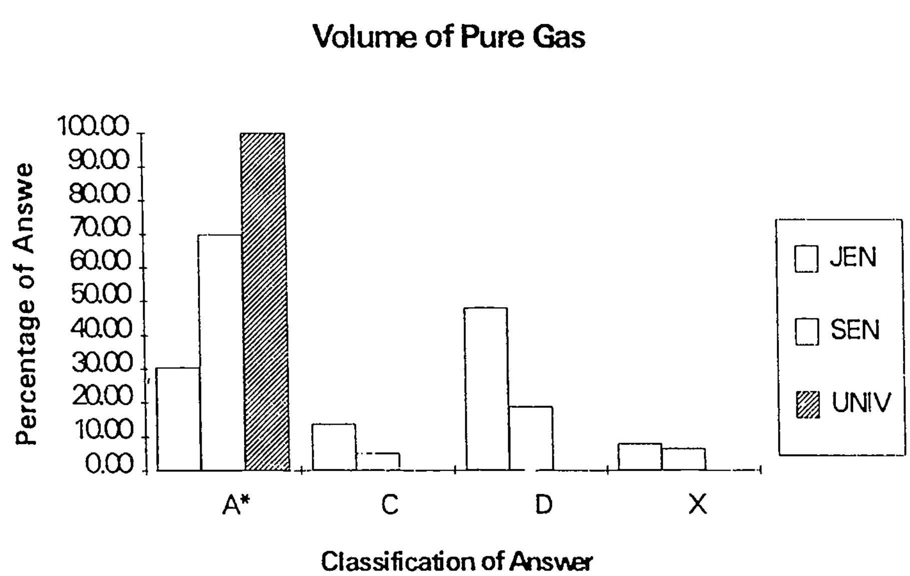

Figure 1 The volume of hydrogen gas in a container with a volume of 1 liter

A* : 1 Liter as the volume of the container (correct answer)
C : The volume of hydrogen is related to the fraction of air components
D : Other responses
X : No response

For junior high school student (Figure 1), there were only 30.40% of the subjects could answer the concept of the meaning of gas volume correctly; for senior high school, the correct percentage of answe was 69.90%.The Misconception to answer the volume of hydrogen gas with ' the percentage of volume of hydrogen in the air ' was 13.70% for junior, 5.10% for senior students.

In Table 2-2, from drawing the size of volume of hydrogen gas in a one-liter container, we evaluated the student's conception about gas volume through particulate theory. The percentages of students who thought that 'the volume of a gas is the size of the particle' were 13.7% for junior, 8.50% for senior. Even university students, 3.4% of them hold this kind of thinking.

Table 2-2 Classification of drawing the volume of gas (Item B1-1)

	SCHOOL LEVELS							
	JUN		SEN		UNI		TOTAL	
categories	count	%	count	%	count	%	count	%
VE*	31	30.40	99	56.30	102	87.20	232	58.70
PV	14	13.70	15	8.50	4	3.40	33	8.40
PR	7	6.90	9	5.10	2	1.70	18	4.60
TH	35	34.30	25	14.20	2	1.70	62	15.70
NX	15	14.70	28	15.90	7	6.00	50	12.70

VE* : the volume of a gas is equal to the volume of its container
PV : the volume of a gas is the size of the particle
PR : the gas can diffuse freely, volume is unfixed
TH : other responses
NX : no response

ITEM B1-2: THE VOUME OF NITROGEN AND OXYGEN RESPECTIVELY IN A 2-LITER CONTAINER AND THE REASON OF EXPLAINATION

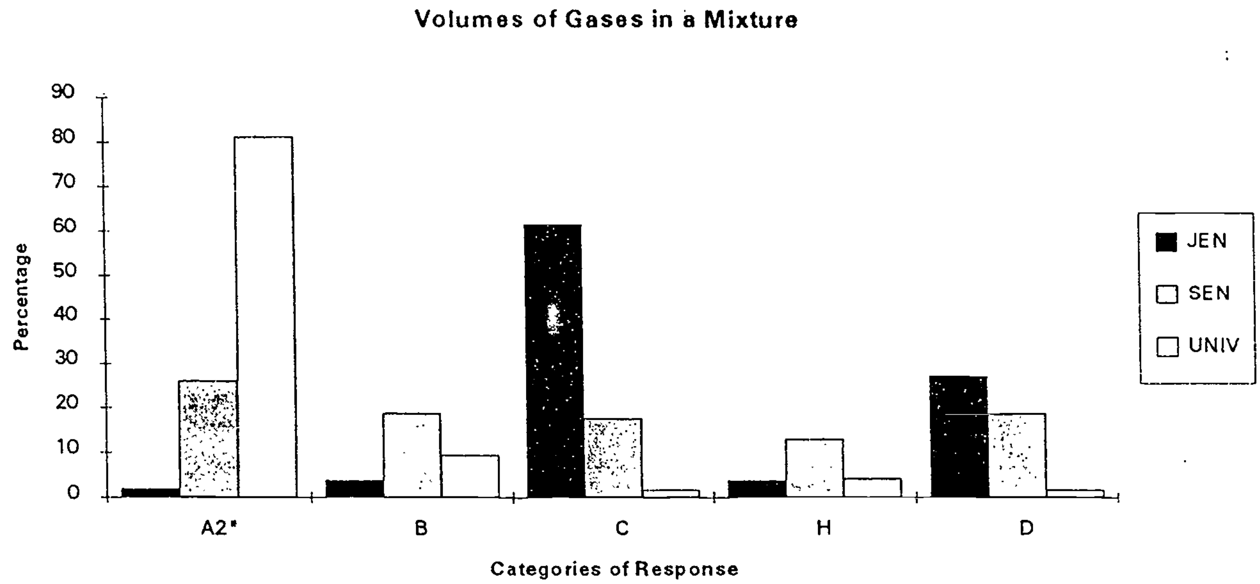

Figure 2 The volume of nitrogen and oxygen in a container

A2*	:	2 Liters (correct answer)
B	:	The volumes of different gases are proportional to their particle numbers in a container
C	:	The volumes of oxygen and nitrogen respectively are related to the composition ratio of the gas mixture
H	:	Each volume of oxygen or nitrogen is 1 liter
D	:	other response

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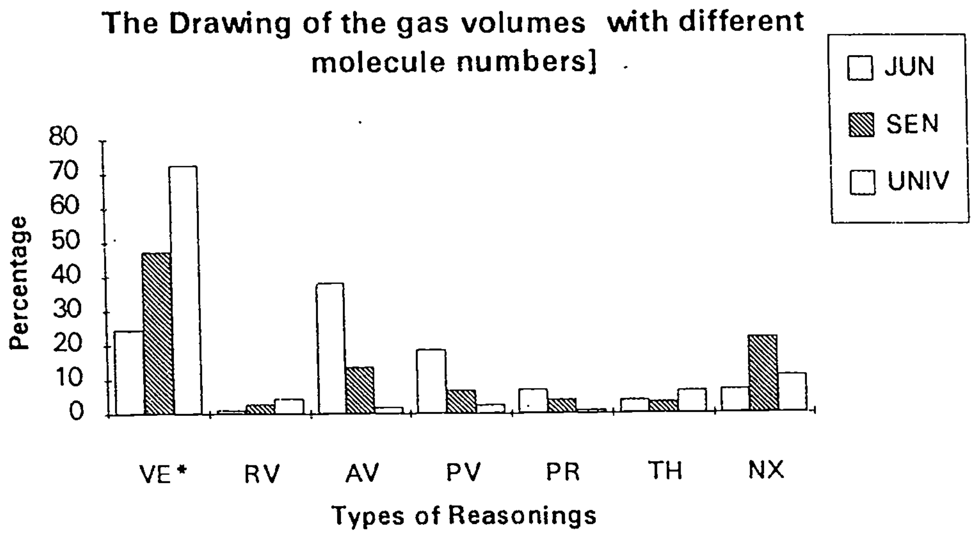

Figure 3 Drawing the size of the volume of oxygen in a vessel which contained a mixture of oxyg :n and nitrogen

VE* :	the volume of a gas is equal to the volume of its container
RV :	the volume of a gas is proportional to its particle numbers
AV :	drewing of the volume of a gas according to student response
PV :	the volume of a gas is equal to the size of the particle
PR :	the gas can diffuse freely, so its volume is unfixed
TH :	other responses
NX :	no response

Table 3-2 Classification of Response of Drawing the Volume of gas (Item B1-2)

	SCHOOL LEVELS							
	JUN		SEN		UNI		TOTAL	
categories	count	%	count	%	count	%	count	%
VE*	25	24.5	83	47.2	85	72.6	193	48.9
RV	1	1.0	5	2.8	5	4.3	11	2.8
AV	39	38.2	24	13.6	2	1.7	65	16.5
PV	19	18.6	12	6.8	3	2.6	34	8.6
PR	7	6.9	7	4.0	1	0.9	15	3.8
TH	4	3.9	6	3.4	8	6.8	18	4.6
NX	7	6.9	39	22.2	13	11.1	59	14.9

ITEM B-2: COMPRESSIBILITY OF GAS:
Is it possible to put 2-liter oxygen into a 1-liter container?
Explain the reason.

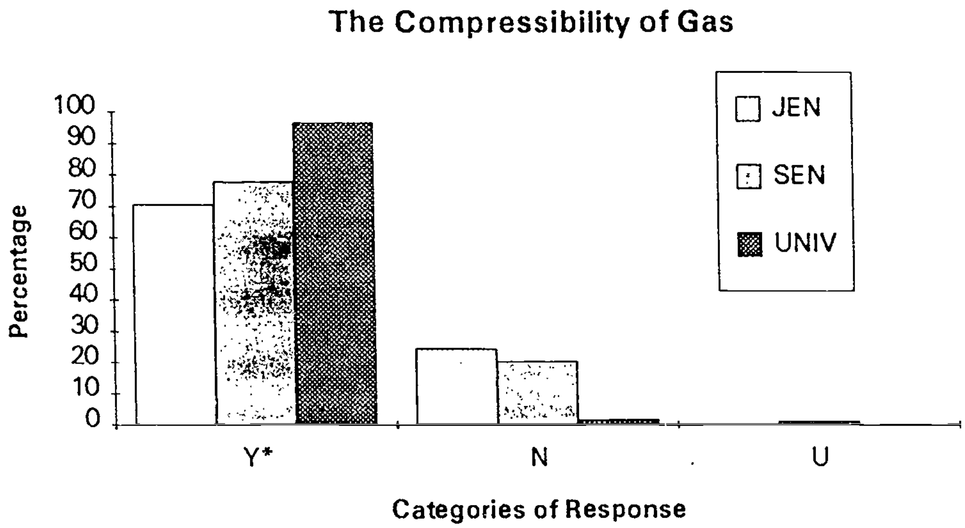

Figure 4 Putting 2 liter oxygen into a 1-liter container

Y* : a two-liter gas can be placed in a one-liter container
N : a two-liter gas cannot be placed in a one-liter container
U : uncertainly or not surely

Table 4-2 Categories of Reasoning of Pure Gas Volume (Itm B2)

		SCHOOL LEVELS							
		JUN		SEN		UNI		TOTAL	
	categories	count	%	count	%	count	%	count	%
YES	PS*	44	43.1	92	52.3	94	80.3	230	57.5
	DE*	9	8.8	20	11.4	6	5.1	35	8.9
	SH*	1	1.0	8	4.5	6	5.1	15	3.8
	TH	18	17.6	17	9.7	7	6.0	42	10.6
NO	NE	16	15.7	26	14.8	2	1.7	44	11.1
	SP	0	0	3	1.7	0	1E-39	3	0.8
	AD	9	8.8	7	4.0	0	1E-39	16	4.1

PS* : the volume of a gas can be compressed
DE* : the distance between gas molecules can be reduced
SH* : the volume of a gas is the volume of its container
TH : other responses or no response
NE : a one-liter container is not enough to place two liters gas
SP : the gas will spill over
AD : other responses or no response

ITEM B3: MIXING TWO GASES WITH THE SAME VOLUME

Put one l liter oxygen and 1 liter nitrogen into a container with 2 liter volume (if no chemical reaction happened), describe the volume of these gases respectively. Explain the reason.

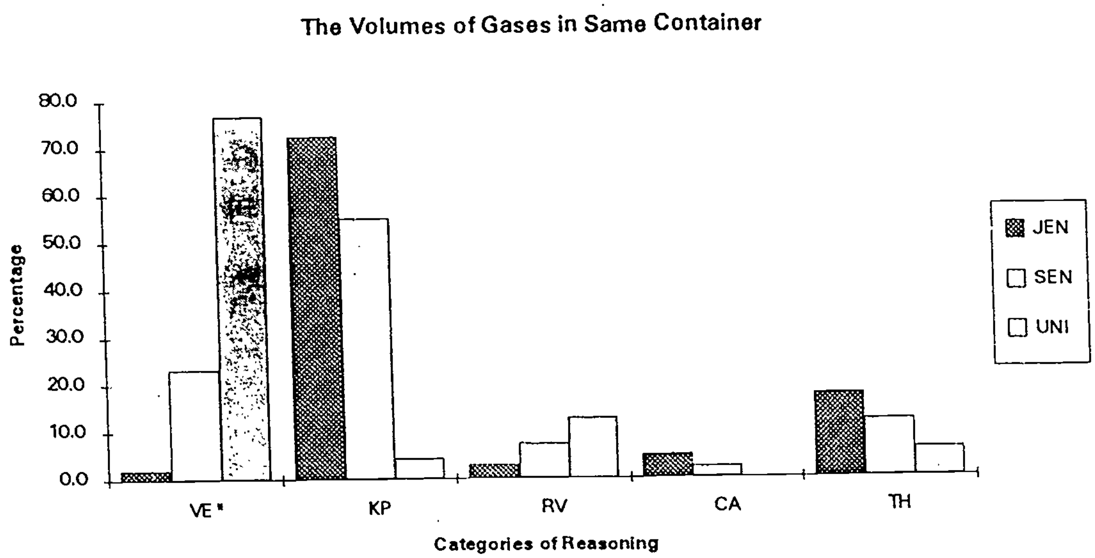

Figure 5 Volume of each gas in a mixture of two gases

VE* : the volume of a gas is the volume of its container
KP : the volumes of oxygen and nitrogen will both remain one liter
RV : the volume of a gas is directly proportional to the quantity of this gas
CA : the volume of each gas in a mixture of oxygen and nitrogen is related to the composition ratio of the air
TH : other responses or no response or no response
NX : no response

ITEM B7: MOLE AND GASEOUS VOLUME:
THE VOLUME OF 1 MOLE OXYGEN IN 1-LITER CONTAINER

Table 6-1 Response to the Relation between Mole and Gas Volume(Item B7)

		SCHOOL LEVELS							
		JUN		SEN		UNI		TOTAL	
answers	categories	count	%	count	%	count	%	count	%
YES:	AV*	33	32.40	91	51.70	108	92.30	232	58.70
	AM	17	16.70	15	8.50	0	0.00	32	8.10
	AX	8	7.80	6	3.40	6	5.10	20	5.10
NO:	CA	16	15.70	3	1.70	0	0.00	19	4.80
	CX	7	6.90	3	1.70	0	0.00	10	2.50
	DI	0	0.00	6	3.40	0	0.00	6	1.50
	DN	2	2.00	3	1.70	0	0.00	5	1.30
	DW	1	1.00	15	8.50	0	0.00	16	4.10
	DX	11	10.80	22	12.50	2	1.70	35	8.90
	NX	7	6.90	12	6.80	1	0.90	20	5.10

AV* : 1 L, the volume of a gas is the volume of its container
AM : 1 L, the volume of one-mole gas is one liter
AX : 1 L, no explanation
CA : 1/5 L, the fraction of oxygen in the air is 1/5
CX : 1/5 L, no explanation
DI : 22.4 , the volume of one-mole gas is 22.4 L (STP)
DN : $6*10^{23}$ liter, avogadro's constant (1 mole = $6*10^{23}$)
DW : 32 L., molecular weight of oxygen is 32
DX : other responses
NX : no response

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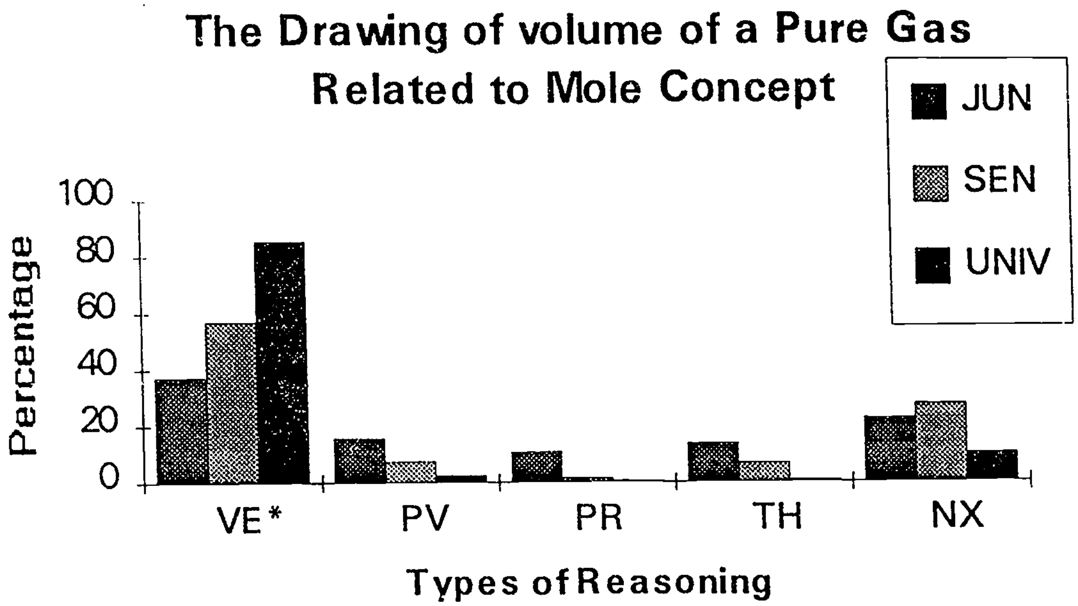

Figure 6 Evaluation by the students' drawing the volume of gas from its number of mole

VE* : the volume of a gas is equal to the volume of its container
PV : the volume of a gas is equal to the size of the particle
PR : the gas can diffuse freely, so its volume is unfixed
TH : other responses
NX : no response

Table 6-2 Classification of Drawing of Gas Volume related to Moles(B7G)

	SCHOOL LEVELS							
	JUN		SEN		UNI		TOTAL	
categories	count	%	count	%	count	%	count	%
VE*	38	37.3	100	56.8	100	85.5	238	60.3
PV	16	15.7	13	7.4	3	2.6	32	8.1
PR	11	10.8	3	1.7	1	0.9	15	3.8
TH	14	13.7	12	6.8	1	0.9	27	6.8
NX	23	22.5	48	27.3	12	10.3	83	21.0

ITEM B8: THE RELATION BETWEEN VOLUMES AND MOLES OF A MIXTURE CONTAINING TWO GASES

Table 7-1 The Response of each Gas Volume to Mole in a Mixture(B8)

		SCHOOL LEVELS							
		JUN		SEN		UNI		TOTAL	
answers	categories	count	%	count	%	count	%	count	%
YES:	AV*	17	16.7	50	28.4	91	77.8	158	40.0
	AM	3	2.9	6	3.4	0	1E-39	9	2.3
	AX	2	2.0	8	4.5	3	2.6	13	3.3
NO:	CA	16	15.7	6	3.4	0	1E-39	22	5.6
	BM	18	17.6	46	26.1	17	14.5	81	20.5
	BX	1	1.0	3	1.7	2	1.7	6	1.5
	TH	36	35.3	38	21.6	1	0.9	75	19.0
	NX	9	8.8	19	10.8	3	2.6	31	7.8

AV* : 1L. The volume of a gas is the volume of its container.
AM : 1L. The volume of one-mole gas is one liter.
AX : 1L. No explanation.
CA : 1/5L. The fraction of oxygen in the air is 1/5.
BM : 1/3L. The mole fraction of oxygen in the gas mixture is 1/3.
BX : 1/3L. No explanation.
TH : Other responses.
NX : No response.

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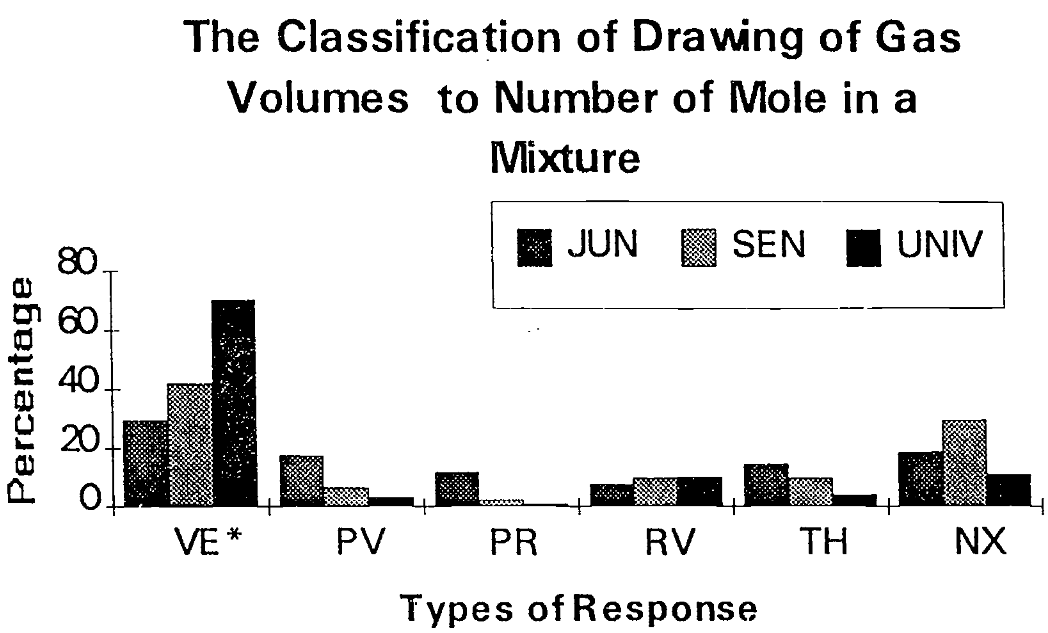


Figure 7 Evaluation of students' concept of gas volumes to number of mole in a mixture by drawing

VE* : the volume of a gas is the volume of its container
PV : the volume of a gas is the size of the particle
PR : the gas can diffuse freely, so its volume is unfixed
RV : the volume of a gas is proportioned to its particle numbers
TH : other responses
NX : no response

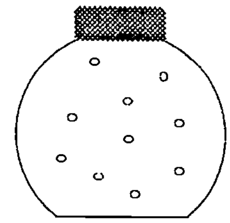
Table 7-2 The Classification to the Drawing of Gase Volume to Mole in a mixture (B8G)

	SCHOOL LEVELS							
	JUN		SEN		UNI		TOTAL	
categories	count	%	count	%	count	%	count	%
VE*	30	29.4	74	42.0	82	70.1	186	47.1
PV	18	17.6	12	6.8	4	3.4	34	8.6
PR	12	11.8	4	2.3	1	0.9	17	4.3
RV	8	7.8	17	10.0	12	10.3	37	9.4
TH	15	14.7	17	10.0	5	4.3	37	9.4
NX	19	18.6	52	29.5	13	11.1	84	21.3

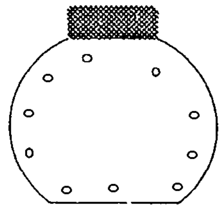
ITEM 1-1:

The figure in the right hand side is the distribution of hydrogen at 25 ^{o}C and 1 atm in a tank.

1-1. Choose the correct answer which can be the distribution of hydrogen gas, if the temperature is changed to - 15 ^{o}C.



(A)



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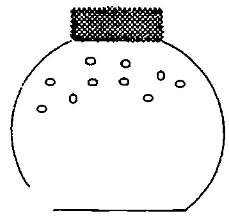

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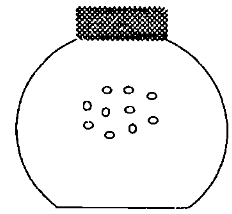

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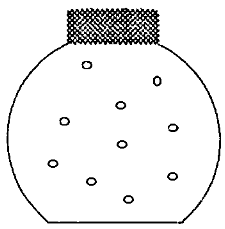

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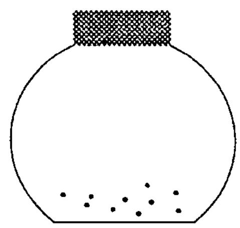

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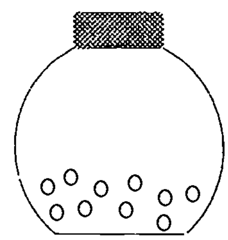

Table 8-2 The Response of Student' Particulate Concept on Temperatur Lowering (Item 1-1)

SCHOOL LEVEL	SEX		A	B	C	*D	E	F	U	TOTAL
JUN	F	n	9	23	68	35	83	21	22	261
		%	3.40	8.80	26.10	13.40	31.80	8.00	8.40	100.00
	M	n	8	9	57	16	57	13	16	176
		%	4.50	5.10	32.40	9.10	32.40	7.40	9.10	100.00
	TOTA	n	17	32	125	51	140	34	38	437
		%	3.90	7.30	28.60	11.70	32.00	7.80	8.70	100.00
SEN	F	n	2	0	2	2	2	2	0	10
		%	20.00	0.00	20.00	20.00	20.00	20.00	0.00	100.00
	M	n	6	3	23	29	9	0	1	71
		%	8.50	4.20	32.40	40.80	12.70	0.00	1.40	100.00
	TOTA	n	8	3	25	31	11	2	1	81
		%	9.90	3.70	30.90	38.30	13.60	2.50	1.20	100.10
UNI	F	n	0	0	14	39	6	0	0	59
		%	0.00	0.00	23.70	66.10	10.20	0.00	0.00	100.00
	M	n	1	3	15	35	2	1	0	57
		%	1.80	5.30	26.30	61.40	3.50	1.80	0.00	100.10
	TOTA	n	1	3	29	74	8	1	0	116
		%	0.90	2.60	25.00	63.80	6.90	0.90	0.00	100.10
TOTAL	F	n	11	23	84	76	91	23	22	330
		%	3.33	6.[illegible]	25.45	23.03	27.58	6.97	6.67	100.00
	M	n	15	15	95	80	68	14	17	304
		%	4.93	4.93	31.25	26.32	22.37	4.61	5.59	100.00
	TOTA	n	26	38	179	156	159	37	39	634
		%	4.10	6.00	28.20	24.60	25.10	5.80	6.20	100.00

* correct answer

Acknowledges

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