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ASSESSMENT OF TEST ITEMS AS MEASUREMENTS OF THE OBJECTIVES OF CERTAIN INSTRUCTIONAL EPISODES

3rd Jury Validation

Background

There is a dearth of studies that are directed toward organizing and evaluating appropriate classroom activities for elementary children, which make use of a major conceptual scientific paradigm or model. A conceptual model of science that has had monumental consequence is the Bohr-Rutherford atomic model, or planetary atom. It has been described as one of the greatest intellectual achievements of all time because it resulted in classifying the elements of the Periodic Table on the basis of electron structures. As such, it deserves a significant and meaningful place in elementary science curricula.

The Study

A set of classroom instructional episodes involving a simplified planetary atomic model has been produced. Each episode has been labeled and subsequently validated

The Validator's Task

Each description of an instructional episode has a lead paragraph giving a specific behavioral objective or goal. The validator is asked to judge whether or not the stated behavioral goal is measured by the multiple choice test item(s) attached to each episode description.

The proposed test items are designed, hopefully, to assess the pupils' ability to recognize, recall, and, in certain cases, apply the facts, concepts and inferences which are the objectives of the instruction.

The validator should read the episode and its proposed test items; he should re-read the goal stated in behavioral terms in the episode, then he should decide if each test item that is proposed for an episode is a measure of the stated goal(s) of that episode. If a test item does not appear to be a measure of the goal(s), please mark that item's identification number with an "X"...do the same for borderline decisions. If the validator has time, it would be greatly appreciated if brief comments accompanied negative decisions. Please write such comments on the test item sheet. Make no mark for items that are acceptable.

ASSESSMENT OF TEST ITEMS AS MEASUREMENTS OF THE OBJECTIVES OF CERTAIN INSTRUCTIONAL EPISODES

4th Jury Validation

Background

There is a dearth of studies that are directed toward organizing and evaluating feasible classroom activities for elementary children which make use of a major conceptual scientific paradigm or model. A conceptual model of science that has had monumental consequence is the Bohr-Rutherford atomic model, or planetary atom. It has been described as one of the greatest intellectual achievements of all time because it resulted in classifying the elements of the Periodic Table on the basis of electron structures. As such, it deserves a significant and meaningful place in elementary science curricula.

The Study

A set of classroom instructional episodes which lead to and include a simplified planetary atomic model has been produced. Each episode has been labeled as to instructional objective, either factual-conceptual, or inferential. The labeled objective of each episode has been validated by an expert jury. A pre generalization that links facts together in terms of abstracted properties such as color, position, number (ordinal, cardinal), degree or type of change, etc. A pupils's attainment will be measured by factual and/or conceptual information embodied in the answers of multiple choice test questions.

The objective of an episode entitled INFERENTIAL or FACTUAL-CONCEPTUAL-INFERENTIAL

The objective of inferential instruction is a change in behavior which has as its outcome the ability to arrive at a decision or tentative conclusion, or the acceptance of a seemingly incontrovertible outcome based upon a mental model without substantial physical evidence, but from reasoning, partial evidence and relevant facts (the existence of potential energy can only be inferred.... the proof of such occurs when the energy is released). The objective of factual-conceptual-inferential instruction is a change in behavior which has as its outcome the ability to apply facts and concepts presented during the episode in question and, in part, earlier episodes to make inferences about the nature of selected physical phenomena. A pupil's attainment will be measured by his ability to recognize a correct inference embodied in multiple choice test items; the test question may describe a new or modified situation to which the pupil will apply the most likely inference.

Assumed example of a FACTUAL-CONCEPTUAL activity within an instructional episode:

Basic <u>facts</u> about general atomic structure are brought together to build the <u>concept</u> of orderly atomic structure of the elements. The instructor lectures briefly on the form and structure of the basic planetary atomic model, starting with hydrogen. He uses the overhead projector or chalkboard to diagram the buildup of several light elements, giving the rules for electron orbit complement. The pupils do likewise; then they use a simple table of atomic characteristics to draw planetary atomic representations of many of the first 20 elements.

Assumed example of a FACTUAL-CONCEPTUAL-INFERENTIAL or INFERENTIAL activity within an instructional episode:

The assumed example of a FACTUAL-CONCEPTUAL activity is extended to include interpretation of a simplified version of the Periodic Table of the elements. The pupils are then invited to make inferences about certain characteristics of elements for which only blanks appear in the Table.

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The Validator's Task

The validator should read each instructional episode and the test question(s) following it. He should then decide if the episode's instructional objective, labeled either factual-conceptual or inferential*, is measured in the cognitive sense described on pages 1 and 2 by the test item(s).

Attainment on an episode labeled inferential which is measured by more than one test item may include some items at a lower level of the cognitive hierarchy than the inferential level. Thus it is possible that an episode labeled inferential* may have attached to it one or more test items at the factual-conceptual level in addition to one or more at the inferential level.

For negative decisions a test item's identification number should be marked with an "X". If time permits, a brief note of explanation would be helpful, and appreciated. Mark "O.K." for acceptable items.

Additional Information

APPENDIX A

Directions to the Jurors

ERIC

APPENDIX B

1st Jury Validation

Background

There is a dearth of studies that are directed toward organizing and evaluating appropriate classroom activities for elementary children, which make use of a major conceptual scientific paradigm or model. A conceptual model of science that has had monumental consequence is the Bohr-Rutherford atomic model, or planetary atom. Though it has been supplanted in advanced scientific enterprises, the planetary model is universally employed as an introductory instructional paradigm in atomic studies. The planetary atomic model led to the classification of all the elements by their electron complement in the Periodic Table; this outcome has been described as one of the greatest intellectual achievements of all time. As such it deserves a significant and meaningful place in elementary science curricula.

The Study

The purpose of the present study is to evaluate the following general hypothesis; a major conceptual scheme of science, the planetary atomic model, can be the basis of instructional episodes for pupils of middle elementary and pre-secondary classes.

The instructional episodes have been compiled and modified from a number of sources which include curricula handbooks, commercial sourcebooks, and even college textbooks. As a judge of the suitability of the instructional episodes you are asked to consider three aspects of each of them. Aspect No. 1 is described on pages 1-4. Aspects No. 2 and No. 3 are described on page 4.

Aspect No. 1

Each episode is labeled with a title which indicates its instructional objective(s), namely, FACTUAL and/or CONCEPTUAL, or INFERENTIAL, or FACTUAL-CONCEPTUAL-INFERENTIAL. The titles are described and assumed examples given below.

The aspect to consider: <u>Does the instructional episode fit the purpose implied by its title in any useful operational sense for pupils in both middle elementary and pre-secondary classes?</u>

The objective of an episode entitled FACTUAL:

The objective of factual instruction is a change in behavior which has as its outcome

...e No.

...f Difference Between ...eans by Sex for Each ...Boys, 9 Girls

...	...-Instructional Standard Deviation	Standard Error of Difference Between Post & Pre Means	t Ratio	Is Gain Significant at α = .01?*
...33	1.0299	.43761	3.2373	Yes
...55	1.0138	.37273	2.6833	No
...00	5.2223	.69982	3.6914	Yes
...57	2.7839	.89765	1.4855	No
...56	3.0289	1.15962	1.6528	No
...55	1.7401	.40826	6.5318	Yes
...56	3.8954	1.18526	4.6403	Yes
...11	3.0596	1.09304	5.7825	Yes

*One-tailed test; degrees of freedom; boys = 11, girls = 8.

knowledge of an event or phenomenon, or assumption, or principle. A pupil's attainment will be measured by his ability to recognize correct factual information embodied in the answers of multiple choice test questions.

The objective of an episode entitled CONCEPTUAL:

The objective of conceptual instruction is a change in behavior which has as its outcome the internalizing of an idea or generalization that links facts together in terms of abstracted properties such as color, position, number (ordinal, cardinal), degree or type of change, etc. A pupil's attainment will be measured by his ability to recognize correct conceptual information embodied in the answers of multiple choice test questions.

The objective of an episode entitled INFERENTIAL:

The objective of inferential instruction is a change in behavior which has as its outcome the ability to arrive at a decision or tentative conclusion, or the acceptance of a seemingly incontrovertible outcome based upon a mental model without substantial physical evidence, but from reasoning, partial evidence and relevant facts (the existence of potential energy can only be inferred.... the proof of such occurs when the energy is released). A pupil's attainment will be measured by his ability to recognize a correct inference which explains a physical event, embodied in the answers of multiple choice test questions.

The objective of an episode entitled FACTUAL-CONCEPTUAL-INFERENTIAL:

The objective of factual-conceptual-inferential instruction is a change in behavior which has as its outcome the ability to apply facts and concepts presented during the episode in question and, in part, earlier episodes to make inferences about the nature of selected physical phenomena. A pupil's attainment will be measured by his ability to recognize a correct inference

Item Analysis of Test

Revisions of the measurement instrument, resulting from analysis of the pilot class performance, are summarized in Table No. 2, Appendix B.

In certain cases an item was retained with revision, even though in the original form the item discriminated poorly between high and low scorers and/or the difficulty index was low or high. Items that were revised or dropped were done so as a result of interviews with high-scoring children and the teacher.

All of pilot episode no. 14 was dropped because of difficulty expressed by pupils and teacher with the concepts of electron energy levels to account for certain phenomena associated with spectral color and X-rays. The most basic limiting factor appeared to be that the activities did not provide enough preparation in the conservation principle. In addition, simple, direct demonstration materials were not commercially available, nor could they be developed

Appendix B, Table No. 2

Pilot Class: A Summary of Item Analysis from the Pilot Post-Instructional Measurement Instrument and the Item Distribution for the Experimental Run: N=21 Pupils

Item No. Pilot Class	Item Difficulty, Percent Correct	Upper 27% of Class	Lower 27% of Class	r_b= Index of Item Discrimination or Validity	Decision*	Item No. for Experimental Run
Factual-Conceptual; Background Items, n=4						
7.1	67	83	50	.37	M	7.1
7.2	48	50	50	.00	R	7.2
7.3	81	100	50	.68	M	7.3
7.4	33	50	17	.37	M**	7.4
Factual-Conceptual; PAM Items, n=12						
9.1	29	67	17	.51	M	9.1
9.2	14	17	17	.00	R	9.2
9.3	57	100	50	.68	M	9.3
9.4	29	33	0	.57	M	9.4
12.1	57	100	17	.84	-	12.1
12.2	52	83	00	.83	-	12.2

(continued)

Item No. Pilot Class	Item Difficulty, Percent Correct	Upper 27% of Class	Lower 27% of Class	r_b= Index of Item Discrimination or Validity	Decision*	Item No. for Experimental Run
		Factual-Conceptual; PAM Items, n=12 (continued)				
12.3	43	83	00	.83	-	12.3
12.4	48	83	17	.64	M	12.4
12.5	43	50	33	.18	R	12.5
13.1	48	50	33	.18	M***	13.1
13.2	33	33	33	.00	R***	13.2
13.3	33	67	00	.76	M***	13.3
		Inferential; Background Items, n=16				
1.1	90	100	83	.44	M	1.1
2.1	43	33	00	.57	M	2.1
3.1	33	83	00	.83	-	3.2
3.2	76	100	83	.44	M	3.1
4.1	14	17	00	.42	M	4.1
5.1	48	83	33	.50	M	5.1
5.2	67	100	67	.59	M	5.2

(continued)

ADDITIONAL CRITERIA AND INFORMATION RELEVANT TO ASSESSING THE EPISODES

1. In your decisions, do not give major emphasis to possible language problems. The episodes accepted from the present validation process will be subject to further assessment and to the scrutiny and criticism of the teachers who will present the activities to their own classes.

2. All episodes which are accepted will be taught to all experimental classes that comprise the two major grade categories for the study, namely, middle elementary (grades 3 and 4) and pre-secondary (grades 5 and 6).

3. An effort has been made to choose episodes and modify them so that pupil-teacher interaction is maximized. The most common method of instruction for the episodes will be discussions which include lecture-discussion, demonstration-discussion, and short laboratory-type activities followed by discussion. Several episodes have provision for reinforcement activities.

4. Several episodes carry the sub-label entitled "background". Their purpose is to give the pupils preliminary experiences in dealing with unseen factors or entities.

5. Several episodes relate to findings or evidence that postdate initial development of the planetary atomic model. This in no way confounds the purposes of the activities as a whole because a rigorous planetary atomic model is not being employed, nor is it limited to knowledge at a certain point in time. For example, the neutron was "uncovered" a number of years after the major postulates relevant to the planetary atomic model were introduced.

6. Certain aspects* of the validity of each of 25 proposed classroom instructional episodes are in question. You are asked to judge the content and purpose of the proposed episode in respect to the several stated aspects*. Your judgment and that of others will be compiled to obtain an assessment for each episode. A sample rating sheet is presented on page no. 6. An individual rating sheet is provided on the page following each episode. The items on the rating sheet coincide with the stated aspects*.

*described on pages 1-4, herein.

r_h = Index of Item Discrimination or Validity	Decision*	Item No. for Experimental Run
S, n=16 (continued)		
Neg. Correlation	R	5.3
.08	D	---
.76	-	6.1
.69	M	6.2
.4?	M	6.3
.59	M	8.1
.64	M	8.2
.00	R	8.3
.50	M	8.4
.42	M	8.5
AM, n=16		
.18	R	10.1
.50	M	11.2****
.64	M	11.3

(continued)

Item No. Pilot Class	Item Difficulty Percent Correct	Upper 27% of Class	Lower 27% of Class	r_b = Index of Item Discrimination or Validity	Decision*	Item No. for Experimental Run
			Inferential; PAM, n=16 (continued)			
11.3	81	100	33	.76	-	11.4
11.4	48	83	50	.37	M	11.5
11.5	67	83	33	.50	M	11.1****
11.6	90	100	67	.59	M	11.6
11.7	81	100	50	.69	-	11.8
11.8	62	100	33	.76	-	11.7
14.1	76	100	50	.69	D	----
14.2	71	100	33	.76	D	----
14.3	24	33	17	.21	D	----
14.4	33	33	33	.00	D	----
15.1	43	67	67	.00	R	14.2****
15.2	62	100	17	.83	-	14.1****
15.3	43	67	17	.50	M	14.3
15.4	10	33	00	.57	M	14.4
15.5	48	83	33	.59	M	14.5

(continued)

Item No. Pilot Class	Item Difficulty Percent Correct	Upper 27% of Class	Lower 27% of Class	r_b = Index of Item Discrimination or Validity	Decision*	Item No. for Experimental Run
		Inferential; PAM (continued)				
15.6	52	67	67	.00	R	14.6
15.7	43	67	17	.50	M	14.7
15.8	19	17	17	.00	D	----

*M = modify; R = revise; D = drop

**The investigator discovered a content ambiguity after jury validation and administration to the X and R classes. The ambiguity is described and the treatment noted on the first page of Appendix E.

***Based on the validator's judgment, nos. 13.1, 13.2 and 13.3 were changed from inferential on the pilot run to factual-conceptual on the experimental run. Data for the pilot run were rendered on the same basis as for the experimental run.

****Placement of the item was changed in the test booklet.

APPENDIX C

Sequence of Instructional Episodes

AN INVESTIGATION IN
ELEMENTARY SCIENCE CURRICULUM
EMPLOYING A MAJOR CONCEPTUAL
SCHEMES APPROACH

Instructional Episodes Leading To
and Pertaining to the Planetary Atomic Model

by

S. Harvey Steinberg

January, 1969
revised July, 1969

EPISODE #1

INFERENTIAL (background)

This instructional episode is designed to give children background experience in accounting for certain physical phenomena in terms of entities that are not seen directly.

At the completion of this instructional episode the pupil should be able to select correct statements relevant to the inference that unseen small spaces exist in the structure of certain substances.

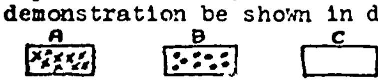
Fill a small beaker with cotton and another beaker of equal size with water. Cram as much cotton in as possible without going over the rim. Use a dropper to transfer the water into the beaker of cotton, and note that the water and cotton eventually seem to occupy the same space. Ask the pupils what may be taking place among smallest bits of cotton and smallest bits of water. During the discussion, the instructor should write the pupils' tentative hypotheses on the chalkboard or overhead projector, then ask the class to evaluate each hypothesis. See summary question no. 2 for the accepted hypothesis. Some children may ask if the process can be reversed, that is, place small bits of cotton into water until the cotton and water seem to occupy the same space. The conclusion is valid both ways.

Summary Questions

1) At normal temperatures nearly all substances (materials) can be grouped by their physical state. solid, liquid, gas. Is cotton a solid or a liquid? [Flexible solid.] Is water as used in this instructional episode a solid or a liquid?, [Solids tend to keep a shape, liquids readily take the shape of the bottom of their containers, gasses fill their containers.]

2) Why do we think that the water fills in spaces within the cotton mass? [The cotton can be removed and nearly all of the water wrung from it.]

3) If drawing A represents cotton and drawing B represents water, how would the results of the demonstration be shown in drawing C?



4) How is a sponge able to hold large amounts of liquid?

New Vocabulary

beaker
flexible
materials
represents
substance

EPISODE #2

INFERENTIAL (background)

This instructional episode is designed to give children background experience in accounting for a change in specific matter in terms of effects which are not seen directly.

At the completion of this instructional episode the pupil should be able to select correct statements relevant to the inference that the substance involved is made up of tiny invisible entities or bits which are in motion.

Pour some ammonia or perfume in a shallow dish. Ask pupils to indicate when they first notice the odor as it diffuses through the air in the room. Invite pupils to suggest an explanation for the spread of fumes (gas) across the room. A reasonable assumption is that a little of the substance escapes (or evaporates) into the air. This idea can be tested by exposing a small quantity of rubbing alcohol to air until it disappears, or let alcohol evaporate from the arms of the pupils.

The pupils should be led into a discussion about the conditions that appear to be necessary for the sensing of odors, and for the evaporation of substances. Ask them to hypothesize which of these situations would most quickly permit them to smell something:

A) The air in the room does not move.

B) The air in the room moves, but the bits or molecules* of the substance do not move.

C) The air moves and the bits or molecules of the substance move.

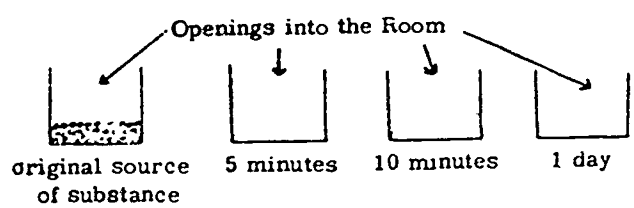
(continued)

*The term molecule is defined more precisely in a later instructional episode. For this episode define molecule as tiny invisible bits or "parts" of the substance.

EPISODE #2 (second of two pages)

Summary Questions

1) If the first drawing shows the substance used in the beginning of the demonstration, fill in the drawings to show the amount of it after the time period indicated.



2) Why does the source substance disappear? Where does it go?

3) Which pupils (as to location) noticed the substance's odor first? Would the results be much different if these same pupils were originally at different locations? How can we be sure?

4) Why can we see the substance at its source, but cannot see the substance as it approaches us? [It changes from a liquid with molecules close together, to a gas with molecules far apart. It is inferred that the molecules are very small, because we can't see them as a gas.]

New Vocabulary

alcohol
ammonia
evaporate
fumes
molecule(s)

EPISODE #3

CONCEPTUAL - INFERENTIAL (background)

This instructional episode is designed to give children background experience in accounting for differential dispersals of a substance in terms of heat associated with it.

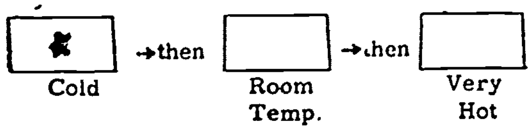
At the completion of this instructional episode the pupil should be able to select correct statements relevant to the inference that the substance involved becomes diffused and the dispersal is dependent on temperature.

Set out three beakers of equal volume. In one beaker put water at room temperature or at the temperature of the cold water faucet. In a second beaker place near-boiling water to a level equal to the water in the first beaker. In the third beaker place two ice cubes and enough cold water to equal the level in the other beakers. Use a dropper to place a few drops of dye solution in each of the beakers, or use a flat wooden splint to put a few particles of powdered dye in each beaker. Ask the pupils to explain what is happening in each beaker. In the ensuing discussion, these hypotheses should be accepted as tenable (1) the dye particles or bits of dye are dispersed or diffused in water, (2) the dispersal per unit of time appears to be dependent on temperature.*

Be sure the pupils understand that the amount of the dye (or dye solution, except for slight evaporation) is conserved... that is, though it spreads out and looks larger, it has done so at the expense of "thickness."

Summary Questions

1) If the first drawing below represents dye solution after 1 minute at cold temperature draw a diagram of the dye solution later on when it warms to room temperature; when it is made very hot.



(continued)

*Pupils may inquire about the possibility of removing sufficient heat to reverse the dissociation of the dye in solution... in other words to make it denser so that the volume decreases. This would require special apparatus which produces temperatures far below the capabilities of common coolants. The volume could not be greatly reduced in any case because of certain "forces" that exist between the particles of the material.

EPISODE #3 (second of two pages)

2) (a) What makes the heated dye solution spread out more rapidly than the cold one?

   (b) Give some examples in everyday life in which heated substances spread out more rapidly than do cooler substances.

3) In an earlier activity the substance could not be seen spreading toward us, but we sensed it by its odor. In the present activity we see the substance spreading; does this show that the bits of dye are in any way different than the bits used in Episode No. 2? Explain. [The bits in Episode No. 2 are each probably smaller than the bits of dye, herein.]

New Vocabulary

Diffusion, Dispersion
Dye
Increase, Decrease

EPISODE #4

FACTUAL - CONCEPTUAL - INFERENTIAL (background)

This instructional episode is designed to give children background experience in accounting for changes in forms of specific matter, in terms of heat associated with it.

At the completion of this instructional episode the pupil should be able to select correct statements relevant to the inference that small, not-easily-seen bits or molecules are kept apart by the heat energy associated with them.

Pour some hot water into a beaker. Place an ice cube on a curved glass dish called a watch glass, and cover the beaker with the glass. Invite the pupils to answer these questions.

1) Liquid is collecting (by condensing) on the lower side of the watch glass. Where does it come from?

2) Look at the area just above the water's surface (higher up the molecules may lose enough energy to come back together as visible vapor before collecting as liquid on the watch glass). Why can't the molecules be seen leaving the surface of the water?

3) On the cold glass, why do the molecules cling together?

The idea to seek from the pupils is that the molecules of water are individually much too small to be seen. However, when the molecules strike the cold glass (why do they travel from the water upward?) something happens and the molecules collect near and on top of one another so that masses of them appear as a fogged portion or film on the glass. Ask the pupils to explain the events observed. [Heat energy or work*, causes the water molecules to increase their motion, until they separate from one another... some fly off into space. When the "fliers" (at high energy) strike the cool (low energy) glass they give up their heat energy to the glass and their energy of motion is reduced; this leads to a tendency** to collect together.]

(continued)

*Energy is defined as the ability to do work. In a subsequent instructional episode, the terms "energy" and "work" will be treated more definitively.

**There is concomitant electrostatic attraction but this idea should not be pursued here.

EPISODE #4 (second of two pages)

4) In the process of condensing, do the molecules themselves get smaller, or do the molecules get closer together? How can we be sure?

[Direct evidence is beyond our capabilities. However, it is inferred that the molecules remain the same size but get closer together as they lose the energy that has caused them to stay apart. The inverse phenomena from which this inference is drawn is demonstrated in Episodes no 2 and no. 3.]

Summary Questions

1) See questions 1-4 above.

2) What is the general effect of heat on molecules as compared to coolness, or loss of heat? [The energy of motion of molecules tends to increase with an increase of heat energy; a loss of heat energy tends to reduce the energy of motion.]

3) Describe several everyday events that can be explained in terms of the instructional experiences herein.

New Vocabulary

condense
decrease
energy
increase
tends, tendency

EPISODE #5

CONCEPTUAL - INFERENTIAL (background)

This instructional episode is designed to give children background experience in making and communicating hypotheses and tests of hypotheses about physical attributes of unseen objects.

At the completion of this instructional episode the pupil should be able to select correct statements referring to: (1) the notions of length, volume, and density as applied to unseen entities in making reasonable estimates about the properties of those entities, and (2) development and testing of mental models of entities whose properties cannot be directly observed.

Activity A

The instructor employs objects of the shapes pictured, then the class is asked to discuss answers to the questions below:

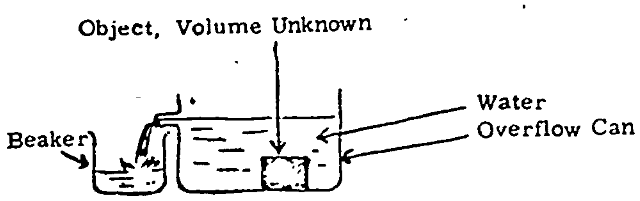
Rectangular (oblong) Cube (square) Sphere Disc (circular) Cylinder Prism (triangular) Pyramid

1) Ask the pupils to identify the shapes.

2) Which object(s) would be easiest to push or pull if they all weighed the same? [The round ones] Why? [Less rubbing]

3) Which object takes up the most volume or space? The least? Use an overflow can as pictured below. The object which makes the most water overflow has the greatest volume. Mark the water level within the beaker by stretching a rubber band around the beaker. Use thin wire tongs to grip and hold down objects that float. Though the wire tong takes up some volume, it is a constant that need not be considered in making the relative measurements, herein. For each measurement be sure the trough is filled up to the level of the spigot and is just ready to commence dripping.

(continued)



4) If the objects were all made from the same substance, which one would weigh the most? Why?

5) If the biggest object is not the heaviest, what can be inferred about the molecules or particles of which it is composed? [Either lighter, or farther apart, or both.]

Activity B

The processes involved in the following part of the activity are analogous to those that scientists use in discovering the properties of unseen entities such as atoms and their sub-particles.

In each of enough boxes (small cardboard, or cigar boxes) for each pupil there has been placed a common object (pencil, metal strip, spool, wood block, etc.) and the box has been "permanently" sealed. These will be used for the "black box" experiment in which the pupil is to use simple manipulations and then build mental models of the box's contents to infer what is inside. He can never open the box; there is an important analogy here with the conception of the atoms of which the world is made. They cannot be seen...all that can be done is to make mental approximations and models of their structure and test these estimates and revise or extend the mental model as experimental results confirm, deny, or confound the model. One of the most important conclusions is that it can be inferred with great certainty what is most probably NOT in the box, and thus some models can be rejected with great certainty; obviously, there is not a real dog inside a box.

By appropriate manipulation, a pupil should be able to estimate the approximate volume of the object (how much space it takes up in comparison to the box), density* (weight/volume), and hence, composition of things that cannot be seen. Invite pupils to estimate the density of the object in the box by "comparing" it to the density of familiar objects. For example, is the object more dense, as dense, or less dense than a coin?, a sponge?

Invite certain pupils to check each other's estimates in front of the class...one child describes his estimate of volume, weight, shape, density on a piece of paper and hands it to the teacher. Another child performs "model-thinking" anew with the same box in front of the class. The teacher compares the two "models" for the whole class.

The teacher should ask the pupils to name some entities that cannot readily be seen, but about which much is known. [electricity, atoms, molecules, magnetism, virus, certain diseases, electrons, air.] Point out that the use of the senses, coupled with imagination are common to answer-seeking projects.

Summary Questions

Activity A. See Questions in Activity A.

Activity B.

1) (a) Give four general characteristics of the contents of the box which can be estimated with reasonable accuracy? [Shape, volume, weight, density.]

(b) Can we be sure that a living thing is not in the box?

*To give the pupils more experience with the concept of density, fill a plastic bag with one pound of loose paper and demonstrate that its much greater volume is balanced by a one pound metal object of much smaller volume. Ask the pupils to explain the difference...accept answers that suggest, (1) greater space between the molecules or particles of paper as compared to the particles of metal, and (2) a difference in the ultimate structure of the particles. Separately weigh the two objects using a spring scale. Adjust the contents of the plastic bag to weigh one pound. Use rubber bands around the closed neck of the bag to hook the bag to the spring scale. To fasten the metal object to the scale, wrap rubber bands tautly around the object and attach to the scale hook.

(c) What can be said about the contents of the box with great certainty? Give examples.

(d) Can the contents of the unopened box ever be known for certain without the use of special instruments?

2) (a) Give some examples in which scientists deal with invisible things with confidence. [See examples, given before.]

(b) Do pupils ever deal with invisible things with confidence? How do they know what the results will be if the object(s) can't be seen?

New Vocabulary

cube
cylinder
density
disc
rectangle (rectangular)
prism
pyramid
sphere
square
triangle (triangular)
volume
oblong

EPISODE #6

FACTUAL - CONCEPTUAL - INFERENTIAL (background)

This instructional episode is designed to impart to children background experience about the principle of work and energy transformations to account for a wide range of physical events.

At the completion of this instructional episode the pupil should be able to select correct statements and/or diagrams that relate to: (1) interpretation of the concepts of energy and work, and (2) the inference that energy transformations result from work.

Pair the pupils. One pupil in the pair repeatedly bends a piece of light-weight coat hanger wire. It is flexed with great rapidity until it breaks. As the wire is flexed the other pupil places a finger upon the flexing point to sense the increasing heat produced. Invite them to explain the source of heat. If the pupils use the word "friction", ask them to explain, friction of what, with what? The problem may become clearer if the pupils, after bending their wires, wave them vigorously through the air in an tempt to produce appreciable heat. Of course, the air ovides very little frictional resistance. The purpose here is to give pupils experience in inferring that small invisible bits (the t m molecule can be substituted here in a somewhat less-than-rigorous sense) of the wire are being moved and separated by an external force. Molecules of the wire are coupled tightly together (how they are coupled is beyond the scope of our studies) and some of the work done to weaken or loosen the couplings shows up as heat. Heat is a form of energy; name other forms such as electrical energy, energy of motion, light energy. Some of the pupils' body chemical energy allowed them to make movements that were ultimately transformed to heat energy in the wire.

Tell the pupils that work (contrast it to common meanings) in science is the measure of energy. For our purposes, the words work and energy can usually be interchanged. Work is defined f : acting through a distance, or which produces movement. A ce is manifested as a push or pull. A subtle but importan concept differentiates a force which produces movement from a force that is incapable of itself in producing movement. Only the former produces work or energy. [The latter may produce only pressure. However, the potential to produce work as in a cocked rifle bolt, is termed potential energy. The concepts of pressure and potential energy will not be pursued in our studies.]

(continued)

Work is capable of transformations. Nearly all appliances in our homes, schools, and industries make energy transformations for us; for example, a radio, in part changes electrical energy to sound energy.

To give the pupils experience in generalizing the important concept of energy transformation, invite them to note and explain the source of the heat produced while a lead block is repeatedly pounded with a hammer. [Some of the energy of motion, in part, moves* lead molecules and part of the energy of motion is transformed to heat as lead molecules collide and resist movement.]

Summary Questions

1) Define these terms and give examples or demonstrate each one:

   (a) force
   (b) work
   (c) energy transformation

2) A boy pushes vigorously trying to make a car move, but it remains stationary. Does he do work on the whole car? Does he do any work? Explain.

3) Who would wear out the seat covers in a car first, a 250 pound woman or a 120 pound woman (assume same amount of time in the car and same kind of cover)?... explain in terms of work.

4) In which of the following situations is work performed? In which one is the most work performed? In which one is the least work performed?

   (a) A boy pushes his cart up a hill.

   (b) A truck rolls down a hill and crashes into a house.

   (c) A bird pulls a worm out of its hole.

   (d) A dog pulls at the end of his leash, but he doesn't move at all.

*The surface becomes dented.

5) In which of the following situations is work transformed (energy changed from one kind to another kind of energy)?

(a) A girl uses an electric hair dryer to dry her curls. Name the energy changes, if any. [Electrical energy is transformed to heat energy.] Where did the electrical energy come from? [Perhaps falling water, as at Niagara Falls... energy of motion.]

(b) The wind scatters fallen leaves all around. Name the energy changes, if any. [No appreciable change of energy in this example; the energy of motion of the wind is imparted to the leaves which also move.]

(c) A girl uses an electric sewing machine to stitch an apron together. Name the energy changes, if any. [Electrical energy is changed to energy of motion of the needle, etc.]

EPISODE #7

FACTUAL - CONCEPTUAL - INFERENTIAL (background)

This instructional episode is designed to give children background experience in applying the principle of energy transformation to entities whose actions are explained in terms of the electrical nature of matter.

At the completion of this instructional episode the pupil should be able to select correct statements about charged particles derived from certain electrostatic demonstrations.

Ask pupils to recall familiar phenomena with static electricity. This activity might well be preceded by using inflated balloons and noting their action on each other and on other objects after they have been rubbed against wool or plastics.

Then proceed to the following demonstration which introduces the basic principle of electrostatics; like electrical charges repel, unlike electrical charges attract.

1) Charge an "ebony" (actually made of hard rubber) rod by rubbing it vigorously several times in one direction with fur. It is known that such action, in effect, upsets the electrical neutrality of the substance of the rod; the action puts a negative (symbol is -) charge on the rod. Bring the ebony rod near the knob of a neutral electroscope...note the action of the electroscope leaves. They will diverge. Touch the ebony rod to the knob...note the action of the leaves. They will probably diverge farther. Remove the rod and touch the knob. The leaves will converge. This action grounds or discharges the charge on the scope, and it returns to electrical neutrality.

2) Repeat No. 1 with an uncharged ebony rod, a glass rod, a pencil, etc.

3) Charge a smooth glass rod by rubbing it very very vigorously several times in one direction with silk. It is known that such action, in effect, upsets the electrical neutrality of the rod; the action puts a positive (symbol is +) charge on the rod. Repeat the steps outlined in No. 1 with the glass rod.

4) (a) Touch a charged ebony rod to the knob of a neutral electroscope, then touch another charged ebony rod to the knob while keeping the first one in place.

(continued)

Describe the action of the leaves. The divergence will increase. What can be concluded about the action of negative charges on each other? [They repel each other.]

(b) Repeat A, but with two charged glass rods. Describe the action of the leaves. What can be concluded about the action of positive charges on each other? [They repel each other.]

(c) What can be concluded about the action of like charges on each other? They repel each other.

5) To the knob of a neutral electroscope, touch a charged glass rod, remove the rod, then touch a charged ebony rod. Ground the electroscope and repeat, reversing the order of the rods. Describe the action of the leaves:* [One type of charge gives a divergence, the other type added to it creates a convergence.] What can be concluded about the action of unlike charges on each other? [Unlike charges tend to attract each other.] One result of such attraction is to neutralize a previously charged body. For example, a positively charged body may be neutralized by negative charges which are attracted to it.

---

*Several suggestions for obtaining satisfactory results with the electrostatic apparatus follow :

1) When a charged rod is "touched" to the electroscope knob, run the rod along its length against the knob. This action maximizes the contact area between knob and rod.

2) Some people produce better electrostatic effects than others. Invite different children to participate.

3) Humid conditions may inhibit maximum results from electrostatic demonstrations.

   (a) The glass rod usually gives the most trouble. Clean the surface by washing in a detergent or wiping with a paper towel saturated with alcohol. Dry thoroughly.

   (b) Humidity in the classroom is usually lowest early in the day.

   (c) An operating electric hot plate in proximity to the demonstration area may dry the air and apparatus. Plug-in well in advance.

As in earlier episodes, unseen entities are manifest here. The principle of repulsion of like charges and attraction of unlike charges is a fundamental one. It should be emphasized that the actions demonstrated are basic to explaining and predicting atomic and sub-atomic events. Encourage the pupils to hypothesize about what may be happening to the tiny bits that make up the ebony, the fur, the glass, the silk and the electroscope leaves. An acceptable hypothesis at this point would suggest that some things are added or are removed* from an electrically neutral object in the production of electrostatic phenomenon.

Summary Questions

1) Describe the energy transformation in this instructional episode. [Energy of motion is transformed to electrostatic energy.]

2) (a) What is meant by an electrostatically neutral object?

   (b) How does a neutral object become charged?

   (c) What is an electrical ground?

3) (a) How do negative charges affect each other?

   (b) How do positive charges affect each other?

   (c) How do positive and negative charges affect each other?

4) Which symbol is used to signify a:

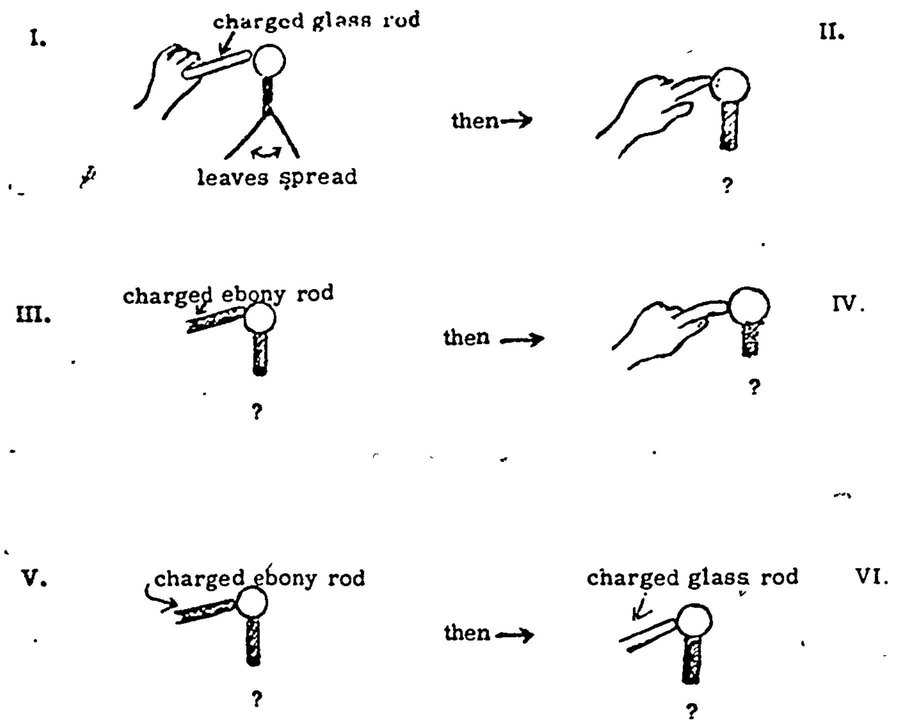
   (a) positive charge? [+]

   (b) negative charge? [−]

   (c) neutralized charge? [O]

*The information that follows will be introduced to the pupils in subsequent episodes. It is known that negative electrical charges are derived from sub-atomic particles called electrons, and positive electrical charges are derived from sub-atomic particles called protons. In common applications, the loss of electrons from atoms makes it possible for the protons to "display" their charges. Taken alone an atom is thought to be electrically neutral, that is, the number of electrons equals the number of protons.

5) On a prepared worksheet (as below) each pupil should complete electroscope diagrams by drawing leaves in the correct position. The upper left diagram is completed as an example. It is suggested that the pupils' work be examined by the instructor to ascertain class progress.



New Vocabulary

attract, repel
ebony rod
electroscope
electrostatic
electrical ground
negative
neutral, neutralized
positive
symbol

EPISODE #8

FACTUAL - CONCEPTUAL - INFERENTIAL (background)

This instructional episode is designed to give children background experience in using basic principles of work and the electrical nature of matter to explain a transformation of energy.

At the completion of this instructional episode the pupil should be able to select correct statements about positive electrical charges (protons) and negative electrical charges (electrons) in relation to (1) their influence on like charges, (2) their influence on unlike charges, and (3) their relative mobility.

Invite the pupils to differentiate between the meaning of the words conductor and insulator, and ask for examples, expecially those in common electrical applications. Tell the pupils that nearly any material, even well known good insulators* can be made to conduct electricity if enough work is done on them.

The demonstration employs an electrophorus; it can achieve a larger charge than that of other inexpensive electrostatic devices. An electrophorus consists of a layer of plastic on a stand and a separate metal charge-carrying disc, which has an insulated handle. Each step is explained (see diagram and information below) from the standpoint of mobility of electrons. When a substance is electrically neutral the quantity of the protons and electrons are in balance. It requires work to unbalance the quantity of charges. Scientists tell us that in common applications, it is the relative mobility of electrons which accounts for the production of electrical effects when appropriate work is done. In general, if the work adds electrons, then negative charges abound, and if the work removes electrons then the effect of positive charges is manifest.**

(continued)

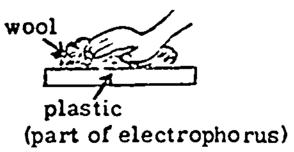
*Wood, normally a good insulator, can conduct, as when a tree or barn is destroyed by lightning. This common danger should be cited to the pupils.

**Some pupils may ask how to identify the polarity (+, -) of an unknown electrical charge. Place a known charge on an electroscope, then place the unknown charge on the scope. The polarity of the unknown charge will be indicated by the convergence (attraction) or divergence (repulsion) of the electroscope leaves.

EPISODE #8 (second of three pages)

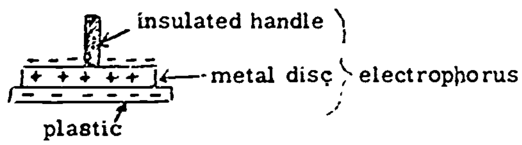
STEP 1

Rub the plastic plate vigorously with wool to charge the plastic negatively; this results in an excess of electrons on the plastic.



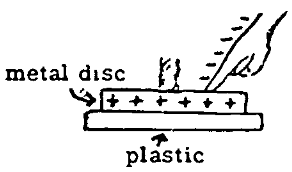
STEP 2

Place the metal disc on the plastic. The electrons of the disc are forced to the disc's top surface (why?) by the action of the excess electrons on the plastic below.



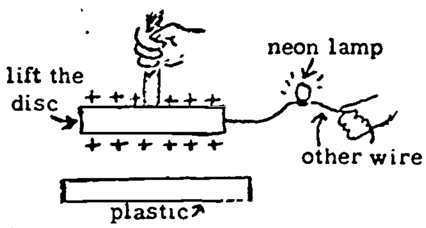
STEP 3

Touch the disc...this action removes the electrons from the top surface of the disc because "ground" is more attractive than the repulsion effect from the negative charges on the plastic plate. The metal disc is now positively charged.



STEP 4

Lift the disc from contact with the plastic plate. Touch the disc to a bared end of a wire lead from a 1/25 watt neon* lamp. A brief red flash of the lamp indicates that an electric charge is flowing across it (from where?) to neutralize the positively charged disc. The "other" wire from the bulb may not require a connection to complete the circuit because the electrons in it may suffice as a source of charges. If the bulb does not flash, clip the "other" wire to a metal object, or even hold the bared end firmly between your thumb and forefinger.



*The neon bulb is a miniature version of the ones used in electrical advertising signs often seen at restaurants and shopping centers, etc. Given an appropriate electrical circuit, neon gas in a bulb will glow a red color.

Show pupils that the light will not flash if no work is done in STEP 1. The emphasis throughout is to give the pupils experience in accounting for the observations in terms of the relative mobility of electrons, as compared to protons.

Summary Questions

1) (a) Usually plastics are electrical insulators. What had to be done to the plastic in this demonstration for it to become electrified?

   (b) Give common examples in which insulating substances may become electrified, or conduct electricity.

2) What specific work was done to produce electricity in the demonstration?

3) Where did the electrons come from to light the bulb?

4) Why did the bulb flash, then go out? [Electrons did work (light energy) "on the way" to neutrality in the disc.]

5) In which steps in this demonstration is it inferred that:

   (a) like electrical charges repel each other? [Step no. 2]

   (b) neutrality was re-established: [When the light flashes and goes out... end of step no. 4.]

6) Scientists tell us that charged particles, and hence, electricity comes from the atoms from which all things are derived or made. Further, scientists tell us that it is negative charges or electrons that are involved in carrying electricity or in "movement" of electricity. In view of this information what part of the atom, "inside" or "outside," would most likely consist of protons? Explain.

New Vocabulary

electron, proton
electrophorus
conductor
insulator
neon

EPISODE #9

FACTUAL - CONCEPTUAL

This instructional episode is designed to impart to children the idea that the universe is composed of a limited number of elements which make up all classes of substances. From earlier episodes the principle of energy transformation is brought to bear on the basic relationships between atoms and molecules.

At the completion of this instructional episode, the pupil should be able to select correct statements which relate to:

1) the definition of chemical element, mixture and compound and the relation between them (rigor of definitions will be sacrificed for ease of comprehension).

2) the definition of atom and molecule and the relation between them (rigor of definitions will be sacrificed for ease of comprehension).

3) the most general qualitative attributes which differentiate the approximately 100 chemical elements at the atomic level.

Referring to some of the materials used in earlier demonstrations such as ebony (hard rubber), glass, wool, silk, wax, leaves of an electroscope, tell the pupil that all things in the world, including plants and animals, sun and stars, are thought to be comprised of one or more of about 100 different elements, in various combinations. Name several well-known elements (iron, silver, aluminum, carbon, hydrogen, oxygen, nitrogen, zinc, radium, uranium, etc.) and relate to pupils' lives and experiences. At this point relate the word atom to the concept of element. Do not push for a deep understanding... it will be treated more rigorously in a later instructional episode. Ask the pupils to give a general hypothesis to explain the existence of so many other substances (give examples such as water, sugar, salt, protein*, wax, silk, ebony, wool, etc.) besides the elementary 100. An analogy may help: in a wardrobe of clothes of different styles, colors, etc., there is a large number of possible combinations that could be worn. However, some possibilities are "more satisfactory" than others. Give examples and let pupils give examples; brown and black shoes

(continued)

*Proteins are a class of complex compounds which give evidence of being involved with the basic chemistry of life in all living things. Proteins are in general composed of the elements nitrogen, hydrogen, oxygen, carbon and often sulfur.

(split pair) etc., vs. 2 browns, 2 blacks, or swimming trunks and T-shirts vs. swimming trunks and overcoat. The important generalization here is that elements may combine, but there are easier or "more satisfactory" combinations with some elements compared to others.

There are two general modes by which substances, including elements, may enter into combination; these modes are mixtures* and compounds. Demonstrations follow which should involve the pupils in differentiating, via discussion, between mixtures and compounds. Use approximately equal and small quantities of powdered zinc (an element) and powdered sulfur (an element). Use a clean end of a wood splint to spoon out once from each container, and mix the powders a bit in a small porcelain crucible. Close the chemical containers before proceeding. Give the pupils a definition for mixture which emphasizes the operational possibility of separating the substances again, "by hand"; demonstrate separation by picking out a few grains of one of the powders.**

Now proceed to make a compound from the mixture of zinc and sulfur. Make a compact mound of the mixture in the crucible, so that it will hold the heat from a burner. With long tongs, hold the crucible over a flaming burner. Be sure the pupils are well away from the reaction because it will produce intense heat and light. Once the mixture starts to glow, remove the crucible from the flame, set the crucible down and stand back...there will be forthcoming a great release of energy. Compare the color of the new compound zinc sulfide (white) with the colors of the original reactants. Zinc is grey, sulfur is yellow. Remind the pupils that the reactants are elements, and re-emphasize the definition of an element. Emphasize that work, in this case, heat energy, was needed to start the reaction and there is a release of energy as a consequence of the reaction that forms the new substance, a compound. Underscore the idea that the compound zinc sulfide did not exist as such before the reaction and that it always forms under the same conditions.

*There are other modes of combinations associated with mixtures, i.e., mixtures of compounds, and mixtures of compounds and elements. An example of the latter is air; examples of the former are products such as Coca-Cola and Bufferin.

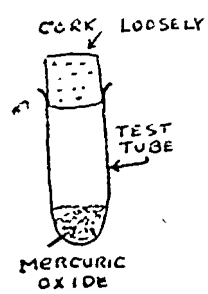
**The proportion of reactants that make up a compound are invariable. However, a mixture can vary in the proportion of its substances. For example, the wheat cereals we buy (Wheaties, Pep, etc.) are made from the same basic compounds, but they are mixed in different proportions to attain a difference in taste.

Put another way, when substances (elements and/or compounds) are put under conditions in which a new compound can be formed, the new compound will always be formed.*

The term molecule can now be introduced in a somewhat more rigorous (but not complete) sense than used in earlier activities; a molecule is the smallest sub-division of a compound that has the compound's properties.** An approximate contrast may be helpful: atoms are to elements as molecules are to compounds.

Some pupils may now ask if compounds can be broken down into their constituent substances. At this point the lesson could be terminated until the next session.

A demonstration of breaking a compound into the elements follows. Place enough of a compound mercuric oxide in a heat-resistant test tube (small) to fill the tube to the level shown in the diagram. Do not let the mercuric oxide cling to the inside wall of the test tube... lightly cork the test tube and heat, moving it back and forth over a flaming burner. When the contents become thoroughly blackened, remove the cork and quickly insert a glowing (not flaming) splint. It should burst into flame;*** this indicates the issuance of the element oxygen. Note the silvery droplets of the element mercury which deposit on the inside of the tube.**** Outline the results on the chalkboard using the following word equation:



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*The compound zinc sulfide could be broken into its constituent elements, but it would require much work or energy to do so. Some other compounds are more easily broken into component elements as will soon be described.

**The term molecule may also apply to polyatomic forms of certain elements, mostly elemental reactant gases under normal conditions.

***If the first attempt fails, cork the tube, reheat and try the test again.

****Referring to earlier episodes, it might be noted that energy is used to change a solid into a liquid and a gas. However, the change here is chemical not physical...Why? [A physical change is limited to a change in shape or a change in state, such as gas to liquid. Chemical changes very often include physical changes but, in addition, there is formed one or more substances with wholly new reactive (chemical) properties.]

(compound) mercuric oxide (molecule)	Add heat energy $\longrightarrow$	(element) mercury (atom)	+	(element) oxygen (atom)

Emphasize that in this case a compound composed of two elements has been broken down to release its elements.* Compare the word equation for the decomposition of mercuric oxide with the earlier reaction in which a compound is formed:

(element) zinc (atom)	+	(element) sulfur (atom)	add heat energy $\longrightarrow$	(compound) zinc sulfide (molecule)

Ask certain pupils to come to the chalkboard to indicate on each word equation where the terms atom and molecule should be properly placed. The emphasis here should be upon the three objectives stated at the top of page 1, not in memorizing word equations.

Invite the pupils to generalize, via discussion, the conditions for making a compound or breaking a compound into its elements. [In both cases energy, or work is required.]

Summary Questions

1) What are the definitions for each of the following terms?

Where relevant, give a common example.

element	compound	energy
mixture	atom	molecule

2) As we have defined them, which would have the most elements represented in it, an atom or a molecule?

3) (a) A scientist breaks a compound into its elements. Which one of the 4 statements below outlines what is thought to happen at the level of the atoms and molecules. Explain. [#2]

1) compound to mixture
3) atom to molecule
2) molecule to atom
4) proton to molecule

*It might be mentioned that many compounds contain more than two elements. One of the most common is sugar which contains the elements carbon, hydrogen, and oxygen.

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3) (b) A scientist creates a compound from certain elements. Which one of the 4 statements above outlines what is thought to happen at the level of the atoms and molecules? Explain. [#3]

4) Scientists tell us that there are approximately 100 different elements which make up all the things in the universe. Which one of the three statements below best states the relation of the elements to the make-up of all substances? [C]

   A) all substances are mixtures

   B) all substances are either elements, or a mixture of elements

   C) all substances are either an element, or are compounds, or are a mixture of elements and/or compounds.

5) When the element oxygen and the element hydrogen are mixed, nothing happens until a spark or flame is introduced into the mixture. Then an explosion occurs and the compound water, in some quantity, is always formed. Relate the substances described above to the terms atom and molecule by filling in the chart below.

	oxygen	water	hydrogen
element or compound?			
atom or molecule?*			

*Oxygen and hydrogen each readily exist in diatomic (two closely associated atoms of the element) form and as such are commonly called "molecules." In these instructional episodes the term molecule will be used only in reference to compounds.

New Vocabulary

atom	molecule
composition	oxygen
compound	reaction
element	splint
energy	substance
mercury	sulfur
mixture	zinc

ERIC

EPISODE #10

FACTUAL - CONCEPTUAL - INFERENTIAL

This instructional episode is designed to give children an experience in recapitulation of certain profound ideas concerning the development of a reasonably valid model of the atomic nature of matter. This episode draws on earlier experiences in electrostatics and making inferences about unseen entities.

At the completion of this instructional episode the pupil should be able to select correct statements concerning the experiment and inferences which led from the Kelvin-Thompson "jelly-roll" model of the atom to the Rutherford-Bohr planetary model of the atom.

Ask the pupils to try to imagine the tiniest entities of which the material of the world is made. Some scientists, not too long ago, imagined these entities or atoms as sort of a spherical ball (see drawings) of jelly-like positive charges in which there would be embedded one or more negative charges, depending on the element. Scientists knew that atoms had negative charges (electrons) and positive charges (protons), but their arrangement was a mystery. They correctly surmised that electrons were responsible for certain manifestations of energy, among them, heat and light. In reference to the jelly-roll idea, if electrons were pulled about within the "jelly" by having work done on them, they would give up energy in the form of heat and light.

Diagram I is an approximate representation of a "jelly-roll" atom which has several randomly arranged electrons and protons. If the "jelly-roll" model is a good one, then high speed, positive* charges, fired at a mass of such atoms from the outside, would be expected to take what path(s)? Invite the pupils to predict what path the proton projectiles would take, and defend their predictions. Then draw Diagram II on the chalkboard. Diagram II represents what was thought would happen if the target atoms were analogous to the "jelly-roll" idea.

If the atom is analogous to the "jelly-roll" conception then the path of proton projectiles should be slightly bent as the projectiles come under the repulsion influence of the randomly-arranged target protons (Diagram II). Electrons of

(continued)

*Protons have much more mass ("weight") than electrons. Therefore, it was expected that protons fired at high speed would not be easily deflected by randomly arranged positive charges of the target nor be captured or slowed by negative charges of the target.

the target might only speed-up oncoming protons by attraction and slow them a bit as the protons pass by. When the pupils seem to understand this logic, then show them what really occurred, as in Diagram III.

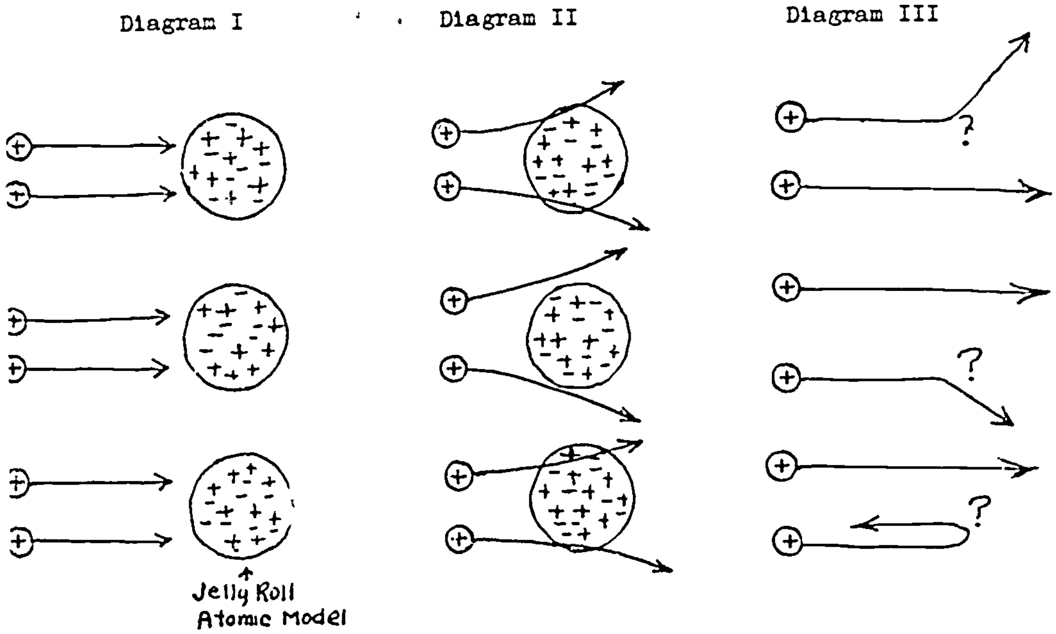
Dramatize that Diagram III represents what happened when Rutherford experimentally tested the "jelly-roll" model of the atom. From the diagram it will be seen that some protons got through unmolested...<u>in fact, most of them did</u>, but a few that didn't were either very sharply deflected, or actually came directly back! The pupils should be led to infer that:

1) atoms seem to be mostly empty space;

2) there is a central portion that has a large, positive charge;

3) the planetary atomic model seems to be a better representation than the "jelly-roll" model.

Diagram I | Diagram II | Diagram III



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* $\oplus\longrightarrow$ represents many, many protons driven at high speeds.

When pupils apparently accept the foregoing, the following questions can serve to extend and reinforce pupils' conceptions about the planetary atomic model.

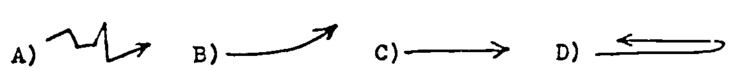
1) For a source of target atoms, Rutherford selected elements having the property of being dense. What was the basis for his reasoning? [High speed protons would more likely be influenced because of more targets.]

2) Assuming there are electrons associated with each atom, what can be inferred about their distance from the nucleus of the atom? [Electrons must be far away and in motion, otherwise the cluster of positive charges in most nuclei would attract them so much that electrons would fall into nuclei.]

3) The planetary atomic model seemed to "solve" some important problems for scientists, but it made problems, too. Can you spot one of them? Hint: consider nuclei which have more than one proton and <u>then</u> recall the rules for electrostatic attraction and repulsion!

<u>Summary Questions</u>

1) If high speed positive particles were fired at atomic targets, which one of these drawings shows the expected path <u>if</u> protons were mixed evenly with electrons throughout target atoms? Explain. ["B". See explanation on p. 2.]



2) Repeat No. 1 except the high speed positive particles are fired at an atomic target with closely packed protons; which arrow(s) represent(s) what occurred in Rutherford's experiments? ["C" mostly, and "D" occasionally.]

3) Scientists claim that atoms are mostly empty space. How did Rutherford's experiment help to infer such a conclusion? [Most of the projectiles went through seemingly solid targets, without being deflected.]

<u>New Vocabulary</u>

atomic target
embedded
deflect

EPISODE #11

FACTUAL - CONCEPTUAL - INFERENTIAL

This instructional episode is designed to impart to children basic understandings about the sub-atomic attributes of selected elements. It draws upon earlier experiences which dealt with the electrical nature of matter.

At the completion of this instructional episode, the pupil should be able to use a chart of atomic properties (p. 5) to select correct statements which relate to a basic body of content on the general structure of the planetary atomic model.

The introductory statements herein should be presented via lecture: In order to account for differences in the elements in such features as color, density, relative conductivity of heat and electricity, relative ability to form gases, liquids, solids, and ability to form new substances, it is evident that there must be differences in the structure (make-up) of the smallest division of an element which has all the properties of that element...an atom of that element.

Based on experiences in earlier activities ask the pupils to consider a difference they noted between zinc and sulfur, both of which are elements; [Color]. Tell them that the last bit of zinc that has all of zinc's properties will be different from the last bit of sulfur that has all of sulfur's properties. These last bits are called atoms. Ask the pupils to make mental comparisons of properties among such familiar elements as iron, oxygen, copper, sulfur, aluminum, etc; (Compare properties of color and common physical state.)

Now, invite the pupils to make general hypotheses about the features of the "smaller-yet", or sub-particles of atoms which could have a bearing on the differences each element's atoms display compared to all other elements' atoms. What is sought here are responses of the following types: "built different", "have different parts", "some have more parts than others", etc. If progress here is too slow, ask why water vs. alcohol (neither are elements, both in their pure form are compounds) have such different properties (demonstrate burning, odor) though they look alike.

At this point, explain that scientists have evidence that the differences between atoms of elements are due to differences in the number and arrangement of three basic types of sub-atomic particles (smaller yet than whole atoms). The three basic particles of atoms are:

(continued)

1) Electron - a negatively charged particle which orbits outside the nucleus or central portion of the atom... there are several likely orbiting paths called shells.

2) Proton - a positively charged (opposite of electron) particle which is found as part of the centrally located nucleus. It has nearly 2,000 times more mass ("weight") than an electron.

3) Neutron - an electrostatically neutral particle which is found in the nuclei of all atoms except the most common type of hydrogen. It can be considered as equal in mass ("weight") to the proton. A neutron is thought to be composed of a positive charge and a negative charge.

On the chalkboard or overhead projector, draw a diagram of a simple atom, such as helium, ^4_2He.

Nucleus contains:

2 protons
2 neutrons
4 = atomic mass ("weight")

Tell the pupils that this is a simplified picture of what is now known; in fact, there is strong evidence that it is not this simple, but is a good start in learning how the world is structured from tiny entities. Ask the pupils which part of an atom, electrons or protons, would they expect to be most easily removed. Remind them of their experiences with electrostatics.

Provide each pupil with the chart of the first 20 elements (similar to the one on page no. 5) for their continual reference. Invite them to make drawings of some of the lighter elements in their notebooks. Point out that all elements, except hydrogen*, have neutrons in their nuclei. Emphasize

*Hydrogen, too, is known to have some atoms with neutrons in the nucleus. Atoms, with more or fewer neutrons than "normal" are called isotopes: many such examples exist with other elements. The compound known as heavy water, contains an isotope of hydrogen. The concept of isotopes is not pursued in these instructional episodes.

that the electrons are arranged about the nucleus in successive shells, according to certain rules (to follow). At first ask them to copy the teacher's chalkboard (or overhead projector) drawings. The teacher should give individual help to assure that pupils are drawing their atomic representations in an orderly fashion.

As some mechanical skill in drawing becomes evident, the pupils should be told the following:

1) The drawings, as we make them, are very much over-simplified. But, it is a good way to begin to learn interesting ideas about the composition of the universe.

2) The electron(s) should be thought of as orbiting in a cloud-like shell* at various relatively "fixed" distances from the nucleus.

3) Most of the atom is empty space. Give the following analogy about an atom of hydrogen: If the nucleus were the size of a golf ball, the electron would be buzzing around it about 2 miles away.

It may prove advisable to terminate the activity here and continue at the next session.

After the pupils have had experience in drawing representations of several light elements, they should be led to "discovering" the following rules for determining the atomic structure, via questions from the instructor, and continual reference to their charts.

1) The atomic number always equals the number of positive charges (protons) in the nucleus.

2) The atomic number equals the number of negative charges (electrons) that circulate around the nucleus of a neutral atom.

3) The atomic mass ("weight") minus the atomic number equals the number of neutrons. For the element chlorine: atomic mass = 35, atomic no. = 17, therefore, the number of neutrons = 18 in a "normal" atom of chlorine.... give other examples for drill.

*For the sake of simplicity, we will draw shells as concentric circles.

4) The number of electrons in the first shell outside the nucleus cannot exceed two.

5) The number of electrons in each of the second and third shells does not exceed eight up through element no. 20.

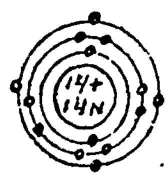
At this point the pupils should be invited to hypothesize about the properties of certain elements, based on our simplified look at atomic structure. For example, ask the pupils to note that in a set of four metallic elements made into cylinders of equal weight, each has a different volume. Invite the pupils to account for the differences discussing it in terms of general atomic structure.* Despite earlier experiences in these instructional episodes, it can be expected that some of the pupils will not have a definitive conception of volume, much less density. However, a conception of weight can be expected, and from this the notion of a difference in density should be re-introduced.

* Aluminum, atomic no. = 13; atomic mass ("weight") = 27
Zinc, atomic no. = 30; atomic mass ("weight") = 65
Tin, atomic no. = 50; atomic mass ("weight") = 119
Lead, atomic no. = 82; atomic mass ("weight") = 207

THE FIRST 20 ELEMENTS:
CHART OF BASIC ATOMIC PROPERTIES

Atomic Number	Element	Symbol	Basic * Chemical Property	Atomic Mass ("weight")	Protons	Neutrons	Electron Arrangement in the shells 1st	2nd	3rd	4th shell
1	Hydrogen	H	M	1	1	0	1			
2	Helium	He	inert	4	2	2	2			
3	Lithium	Li	M	7	3	4	2	1		
4	Beryllium	Be	M	9	4	5	2	2		
5	Boron	B	M	11	5	6	2	3		
6	Carbon	C	Ind.	12	6	6	2	4		
7	Nitrogen	N	Nm	14	7	7	2	5		
8	Oxygen	O	Nm	16	8	8	2	6		
9	Fluorine	F	Nm	19	9	10	2	7		
10	Neon	Ne	inert	20	10	10	2	8		
11	Sodium	Na	M	23	11	12	2	8	1	
12	Magnesium	Mg	M	24	12	12	2	8	2	
13	Aluminum	Al	M	27	13	14	2	8	3	
14	Silicon	Si	Ind.	28	14	14	2	8	4	
15	Phosphorus	P	Nm	31	15	16	2	8	5	
16	Sulfur	S	Nm	32	16	16	2	8	6	
17	Chlorine	Cl	Nm	35	17	18	2	8	7	
18	Argon	Ar	inert	40	18	22	2	8	8	
19	Potassium	K	M	39	19	20	2	8	8	1
20	Calcium	Ca	M	40	20	20	2	8	8	2

Drawing of
silicon (Si) atom
atomic no. =14
no. of neutrons=14
atomic mass ("weight")=28



Electron arrangement of silicon
1st shell = 2 electrons
2nd shell = 8 electrons
3rd shell = 4 electrons

M = mostly acts like metal
Nm = mostly acts like non-metal, however there are important exceptions with nitrogen, sulfur and phosphorus.**
Ind. = indeterminate; can act like a metal or non-metal

*The pupils' charts do not contain the column entitled, "Basic Chemical Property," nor the information entered below row no. 20.

**It might be well to mention to the pupils that there are common exceptions to most of the "rules", or patterns stated herein. There are valid explanations for many of the exceptions, but they are embodied in the content of advanced studies.

Summary Questions

1) In atomic structure where do the negative charges exist?, positive charges?

2) If the atomic number is known, the quantity of what two basic parts of a neutral atom are known? [Protons and electrons.]

3) (a) What two parts of atomic structure make up atomic mass ("weight")? [Protons and neutrons.]

   (b) Describe the electrostatic charge of each of the two parts named in "a". [Protons carry a positive charge. Neutrons carry a positive and negative charge, hence, neutrons are electrostatically neutral.]

4) What are the relative masses ("weights") of these atomic particles?.... Use the terms most, least, same.

   (a) electron (b) proton (c) neutron

5) If the atomic number and the atomic mass ("weight") are known, how can the neutron complement of an atom, be computed? [From the atomic mass subtract the atomic number. Give pupils several examples to work out such as helium, beryllium, oxygen, magnesium, phosphorus, argon.]

6) Given equal volumes, which element would you expect to be heavier, aluminum or magnesium? Why? Use the chart. [Aluminum has more particles in the nucleus.]

7) At ordinary temperatures the following elements are gases: hydrogen, helium, oxygen, nitrogen. Air is a mixture of mostly oxygen and nitrogen. Why are hydrogen and helium used in balloons and dirigibles? Use the chart. [If 4 balloons are each filled with equal volumes of these gases, then the hydrogen and helium balloons would float in air. Hydrogen and helium atoms have less mass ("weight") than do nitrogen and oxygen atoms which compose the air.]

8) Name the element(s) in the chart of the first 20 elements which:

   (a) have the most electrons in their outermost shell. [Neon, argon...each has 8 electrons.]

(b) have the same number of neutrons.
[Boron, carbon = 6; fluorine, neon = 10; sodium, magnesium = 12; aluminum, silicon = 14; phosphorus, sulfur = 16; potassium, calcium = 20.]

(c) have the same atomic mass ("weight"). [Argon and calcium, both = 40.]

9) (a) Which element in the first 20 elements has the most neutrons? [Argon = 22.]

(b) Does it have the greatest atomic mass ("weight")? [No, but argon's atomic mass ("weight") is the same as calcium with an atomic mass ("weight") of 40.]

New Vocabulary

arrangement
atomic mass ("weight")
atomic number
electron shell(s)
nucleus
orbit
outermost
particle(s)
represents
symbol

ERIC

EPISODE #12

FACTUAL - CONCEPTUAL

This instructional episode is designed to give children experience in using the planetary atomic model to classify certain elements as metallic, non-metallic, indeterminants, or inert; these chemical characteristics are employed in accounting for the formation of selected compounds.

At the completion of this instructional episode the pupil should be able to select correct statements which explain (in terms of the planetary atomic model) the tendency of certain elements to (1) act like metals, (2) act like non-metals, (3) be indeterminant as to metal and non-metal, (4) be "inert".

With forceps hold a piece of magnesium ribbon in the flame of a burner until it begins to burn. Avoid looking directly at the flame. Emphasize that the burning is release of energy (heat and light). Invite the pupils to observe the product. Tell the pupils that the element magnesium has combined with the element oxygen from the air. Ask the pupils to use their atomic charts from an earlier instructional episode to help hypothesize a possible explanation for the ready combination of magnesium atoms and oxygen atoms. See diagram on page 2. Invite them to draw a diagram of each atom. The explanation is expected to be difficult to elucidate. The pupils should then be told that some types of atoms tend to effect a complete outer shell by gaining electrons which they "acquire" from other types of atoms. The completion of the outer shell for the first 20 elements follows these rules:

1) A maximum of two electrons can appear in the shell next to the nucleus.

2) A maximum of eight electrons can appear in each of the two more distant shells.

Ask pupils to verify these rules in their atomic charts. Employ a short recitation of examples to help reinforce the verification.

Now, begin a lecture-discussion which uses these rules to eventually elicit hypotheses from the pupils relevant to other possible combinations of some elements. Explain that many elements have a tendency to complete outer shells of their atoms, as in the rules above. Use the analogy that the rich get richer, and the poor get poorer to introduce the concept that atoms with fewer than four electrons in their outermost shell tend to share or even lose their outer electrons to yield a complete shell (next shell in toward nucleus)

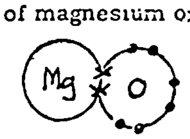
(continued)

and those that have more than four electrons (except those that have eight electrons in the outer shell) tend to take on electrons to complete a shell. Emphasize the tendency to complete outer shells by sharing (or giving up), or by gaining electrons. Atoms with exactly four outer electrons, such as carbon, may go either way and are herein called indeterminant. Atoms that tend to share or lose electrons and thus expose a complete (or more complete) shell nearer to the nucleus are called metals. Atoms that tend to gain electrons to complete a shell are called non-metals. Give examples of common metals such as magnesium, iron and aluminum in the first 20 elements. The gas hydrogen may act like a metal because of its tendency to share its lone electron. Invite the pupils to give other examples of metals. Next, give examples of non-metals in the first 20 elements...ask the pupils to do likewise using the rules outlined above. Certain elements have filled outer shells and are called the inert elements.* They are not likely to enter into chemical combinations. The inert elements, where found, are uncombined or free.

A worksheet (see p. 3) is employed to give the pupils experience in using the atomic chart from an earlier instructional episode to confirm the chemical characteristics of the first 20 elements as being metallic, non-metallic, indeterminant, or inert. For each element the pupil selects one of the four characteristics and also a rationale or explanation, labeled A, or B, or C, or D. Several examples are given.

Plan to take sufficient time with the Worksheet on the Basic Chemical Properties to insure that most of the pupils can demo[illegible]trate a facility with the rules. Then ask the pupils to recal[illegible] demonstration with magnesium [illegible]d oxygen...invite the pupils to give an explanation for the combination of these two elements and the release of energy. An acceptable explanation would suggest that magnesium's two outer electrons are shared by oxygen, forming the compound magnesium oxide. Furthermore, enormous numbers of atoms are combining by the sharing of electrons to form the new substance. The energy given up in the form of heat and light was, in effect, the energy that

Diagram of molecule of magnesium oxide



Magnesium's outer electrons = XX

Oxygen's outer electrons = ••

*In the first 20 elements, the following elements have filled outer shells: helium, neon, argon.

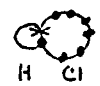
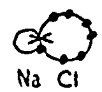
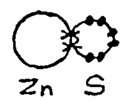
kept the metal magnesium and the gas oxygen in their respective uncombined forms. When they combined (it took some heat energy to start it), they gave up their "excess" energy. It may require two or more sessions to reach this point in the presentation.

As a consequence of the experiences outlined above, invite the pupils to discuss and diagram the hypothetical electron exchanges, if any, between some other elements; a selection follows on page 4. The pupils should attempt to make their own diagrams (as shown) of the electron complement of the outer shells in the appropriate cases, and certain pupils could be asked to put their representations on the chalkboard. The discussion should be supplemented where necessary by the teacher's chalkboard diagrams.

WORKSHEET ON THE BASIC CHEMICAL PROPERTIES OF THE FIRST 20 ELEMENTS

A = outer electron shell is filled (8 electrons except for helium which is filled by 2 electrons)
B = outer electron shell has 1, or 2, or 3 electrons (less than 4)
C = outer electron shell has 5, or 6, or 7 electrons (more than 4, but less than 8)
D = outer electron shell has 4 electrons

Atomic No.	Element	Acts like Metal	Acts like Non-Metal	Can act like Metal or Non-Metal (Indeterminant)	"Inert"	Letter of Reason
1	Hydrogen					
2	Helium				X	A
3	Lithium					
4	Beryllium					
5	Boron					
6	Carbon			X		D
7	Nitrogen					
8	Oxygen		X			C
9	Fluorine					
10	Neon				X	A
11	Sodium					
12	Magnesium					
13	Aluminum					
14	Silicon					
15	Phosphorus					
16	Sulfur					
17	Chlorine					
18	Argon					
19	Potassium	X				B
20	Calcium					

Hydrogen and chlorine	Hydrogen's electron can, in effect fill chlorine's outer shell which contains 7 electrons, thus completing hydrogen's (up to 2 electrons) and chlorine's (up to 8) outer shells. Diagram of hydrogen chloride molecule showing hydrogen's outer electron (x) and chlorine's outer electrons (••) 	Compound formed is hydrogen chloride (HCl), a gas used to make a very useful acid.
Sodium and chlorine	Analogous to above 	Compound formed is NaCl, common salt, found expansively in nature.
Neon and helium	No reaction, ordinarily; both shells filled	
Argon and oxygen	Argon has a filled (8 electrons) outer shell and will not react, ordinarily.	
Zinc (not in first 20 elements) and sulfur	Zinc has 2 outer electrons, hence, they can be shared with sulfur's 6 outer electrons; this, in effect, completes the outer shell for both elements. Diagram of zinc sulfide molecule showing zinc's outer electrons (xx) and sulfur's outer electrons (••) 	Compound formed is ZnS, zinc sulfide (the reaction was demonstrated.)

In each of these cases, after the pupils have worked out the possibility, tell them the name and importance of the compound formed (if any). Terminate the activity at any time that confusion overtakes apparent progress. Continue at the next session with a review; use short lecture and examples on chalkboard, and ask pupils to discuss their reasoning. Invite questions.

EPISODE #12 (fifth of five pages)

Summary Questions

Questions which summarize the expectations stated in the lead paragraph are implied in the work sheet activities.

New Vocabulary

maximum - minimum
indeterminant
inert
product
tends, tendency

ERIC

EPISODE #13

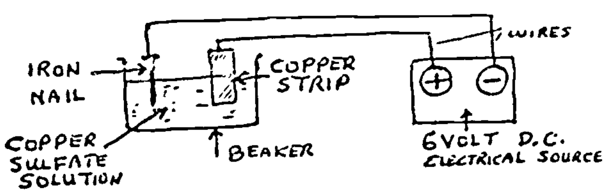
FACTUAL-CONCEPTUAL

This instructional episode is designed to give children experience in accounting for the phenomenon of atomic polarity (charged atoms). Principles of electrostatics and chemical characterists of classes of elements are drawn from earlier episodes.

At the completion of this instructional episode the pupil should be able to select correct statements about the nature of charged atoms following a demonstration of electrolysis.

Fill a small beaker 2/3 with warm water. Stir in about 1/2 teaspoonful of copper sulfate crystals ($CuSO_4$) until most of the crystals dissolve. The solution will have a bright blue color. Connect a clean* copper strip and a clean iron nail to a 6 volt D.C. electrical source as shown in Diagram I. Immerse only the copper strip and the nail in the solution, not any of the terminal or supporting apparatus. The copper strip and nail should not touch each other.

Diagram I



+ = positive pole

− = negative pole

Soon a deposit of copper "threads" will appear on the iron nail and at the same time the copper strip attains a rather etched surface.

The pupils should be invited to discuss the following problem: How can copper atoms, which are said to be electrically neutral (see Diagram II), be pulled from a copper strip, migrate, and be deposited elsewhere?**

(continued)

*Use scouring powder, or steel wool, or fine sandpaper.

**Only the migration of copper is considered herein. In any electrolysis there is some type of reciprocal action.

Diagram II

Neutral Atom of Copper*

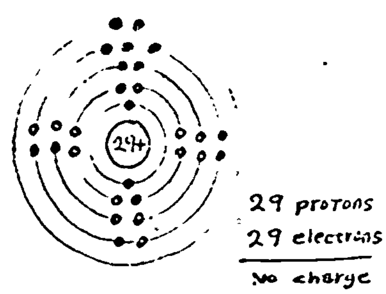
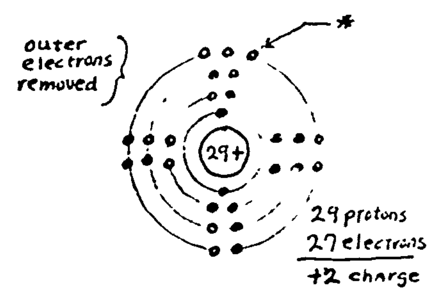


Diagram III

Charged Atom of Copper



[The electrical source does work to remove the two outer electrons from the neutral copper atom. This leaves 27 electrons, and, of course, the 29 protons...hence, the atom now displays two positive (+2) charges and is called a charged copper atom; see Diagram III. Positively charged copper atoms are attracted to the iron nail which is the negative pole of the electrolysis circuit. At the negative pole each charged copper atom, in effect, re-acquires two electrons and is neutralized; it is the neutral atoms which cling loosely to the iron nail.]

The following questions and activities should be woven into the discussion from which the main inference is to be derived.

1) What is the function of the electrical source? [It provides energy, or does work, to move electrons.]

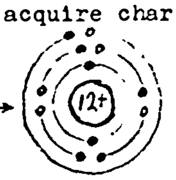
2) What must be done to an atom of an element for it to become charged? [Electrons must be added or taken away.]

3) Explain why the copper is removed at the positive pole in electrolysis and deposited at the negative pole. [See first paragraph, this page.]

*The element copper does not follow the rule for completion of electron shells as given in an earlier instructional episode. This exception is not part of the lesson at hand. Copper was selected for the demonstration because it so readily shows the overall effects stated in the objective for this instructional episode.

4) Atoms of other elements can acquire charges. Draw diagrams of the following:

(a) an atom of magnesium →



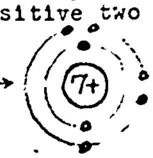
12 protons
12 electrons

(b) a charged atom of magnesium; explain the difference between a and b. →

12 protons
? electrons [10]
2 positive charges

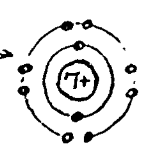
[Magnesium, a metal, has two outer electrons which it can readily give up. The loss of these two electrons unbalances the electrical neutrality of the atom, and "exposes" two protons. Thus, a charged magnesium atom has a positive two charge.]

(c) an atom of nitrogen →



7 protons
7 electrons

(d) a charged atom of nitrogen; explain the difference between c and d. →



7 protons
? electrons [10]
3 negative charges

[Nitrogen, in this case, is to be considered a non-metal (there are important exceptions for nitrogen). It tends to acquire three electrons to complete its outer shell. The gain of the three electrons unbalances the neutrality of the atom by a factor of three negatives. Thus, a charged nitrogen atom has a negative three charge.]

Summary Questions

1) See questions No. 1 - 4. above.

2) In an earlier instructional episode. we learned that some elements are metals. some are non-metals. some may act both as a metal or a non-metal. and some are inert. In regard to the metals and non-metals of the first 20 elements. which ones tend to:

(a) lose electrons to become charged atoms? [H, Li, Be, B, Na, Mg, Al, K, Ca.]

(b) gain electrons to become charged atoms? [N. O, P, S, Cl.]

3) If the compound water is electrolyzed. the elements oxygen and hydrogen are obtained.

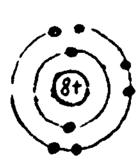
(a) Which drawing, A or B. represents a neutral atom of hydrogen; a charged atom of hydrogen? Explain. ["B" represents the neutral atom...the protonic charge is balanced by charge on electron.]

(A)  (B) 

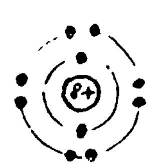
(b) To which pole in electrolysis would a charged atom of hydrogen be attracted? Why? [The negative pole, because hydrogen's outer electron is removed in electrolysis, thus displaying its protonic (+) charge.]

(c) Does it act like a metal or non-metal? Explain. [Metal; it tends to share or even give up its electron.]

(d) Which drawing. C or D. shows a neutral atom of oxygen; [C] a charged atom of oxygen? [D]



C



D

(e) To which pole in electrolysis would a charged atom of oxygen be attracted? Why? [The positive pole, because oxygen acquires two electrons to fill its outer shell, and thus displays two "excess" negative charges in comparison to its 8 protonic charges.]

(f) Does it act like a metal or non-metal? Explain. [Non-metal; it tends to acquire electrons to fill its outer shell.]

4) (a) Draw a picture representing a charged atom of each of the metallic-acting elements of the first 20 elements.

[$_1H$ = no electron, shows positive one charge

$_3Li$ = two electrons, shows positive one charge

$_4Be$ = two electrons, shows positive two charge

$_5B$ = two electrons, shows positive three charge

$_{11}Na$ - ten electrons, shows positive one charge

$_{12}Mg$ = ten electrons, shows positive two charge

$_{13}Al$ = ten electrons, shows positive three charge

$_{19}K$ = eighteen electrons, shows positive one charge

$_{20}Ca$ = eighteen electrons, shows positive two charge.]

(b) To which pole in electrolysis would each of these charged atoms go? Why? [To the negative pole, because each shows at least one positive charge.]

5) (a) Draw a picture representing a charged atom of the elements which tend to act like non-metals* in the first 20 elements.

[$_7N$ = ten electrons, shows negative three charge

$_8O$ = ten electrons, shows negative two charge

$_9F$ = ten electrons, shows negative one charge

$_{15}P$ = eighteen electrons, shows negative three charge

$_{16}S$ = eighteen electrons, shows negative two charge

$_{17}Cl$ = eighteen electrons, shows negative one charge.]

(b) To which pole in electrolysis would each of these charged atoms go? Why? [To the positive pole, because each has taken on at least one additional negative charge.]

New Vocabulary

charged atom
electrolysis
pole

*There are very important compounds of nitrogen, sulfur and phosphorus, in which these elements each act like metals. These profound exceptions are studied in upper level sciences.

ERIC

EPISODE #14

FACTUAL - CONCEPTUAL - INFERENTIAL

This instructional episode is designed to give children experience in using a simplified Periodic Table of the elements to make inferences about elements whose chemical characteristics and atomic structure have not been previously studied.

At the completion of this instructional episode the pupil should be able to select correct statements concerning certain characteristics of some of the more common elements by using a simplified version of the Periodic Table of the elements.

In part, the present episode is designed to give the pupils an introductory experience in predicting some characteristics of certain elements as a simple Periodic Table is built-up. Earlier, the pupils were introduced to concepts relevant to the planetary atomic model including atomic number, atomic mass ("weight"), electron shells and the general principle that the chemical characteristics are a function of the complement of electrons, especially those in the outer shell. Also, the pupils have had experience interpreting a simple, non-periodic table of the basic atomic structure of the first 20 elements.

A simplified version of the Periodic Table of the elements will be introduced. Each student receives a blank Table; an identical one is projected via overhead transparency by the instructor. As the rules for building the Table are developed by lecture and practiced by the pupils, the teacher should invite them to predict what might follow, in terms of (1) electron shell structure and nuclear complement, and (2) chemical and physical characteristics, based on what the pupils already know about common elements such as oxygen, iron, sulfur, magnesium, aluminum, lead, etc. The following basic facts and principles should be imparted via lecture-discussion-recitation. If the pupils become confused, or have difficulty concentrating on the procedures, be prepared to terminate the activity for the day...try again the next session, placing special emphasis on asking the children to explain to each other the basic system of organizing the Table.

1) The Periodic Table of the elements helps to organize and classify much information about the elements and one can avoid memorizing a great amount of detail by learning to interpret it.

2) The Periodic Table is arranged according to increasing atomic number (atomic number equals number of protons, and number of electrons) in such a way that similarity is shown between the number of shells and the number of electrons in the outermost shell. The atomic number

(continued)

appears below the symbol of each element. The atomic mass ("weight") appears above the symbol. Basic concepts relevant to atomic number, proton and electron complement and atomic mass ("weight") have been presented in earlier episodes.

3) The elements are arranged in columns and rows.

(a) Columns - This is the vertical alignment of the Table. Each column's elements are somewhat similar in chemical or reactive properties because they have the same number of electrons in the outermost shell. The number of electrons in the outermost shell appears in the heading for each column.

(b) Rows - This is the horizontal alignment of the Table. Each row contains elements which have the same number of electron shells. The number of shells for each row appears left-most on the Table.

The pupils should be invited, concomitant with the lecture, to fill in their blank Periodic Tables for the first 20 elements. They may be allowed to copy other well known elements as indicated on the instructor's reference table, directly from the instructor's projection overlay. The electron complement should be filled in; for example, No. 12 would be 2-8-2. The pupils should be asked to use the information they are building into their Tables to draw diagrams of various atoms on separate sheets. Certain students could be asked to put their drawings on the chalkboard and explain them. Although this portion of the current episode is a repetition of an earlier activity, it is expected that the reinforcement will have a salutory effect on learning.

As the mechanical process of filling in the Table begins to proceed with greater ease, the pupils should be asked to predict some of the characteristics (see questions Nos. 1 - 4 below) of elements that are yet to be charted in the Table; also, ask for predictions about several of the approximately 60 other elements not provided for in our simplified version of the Periodic Table. The query should include the following:

1) Relative mass ("weight") - Would the same volume of element No.__ be lighter, heavier, or have the same weight* as element No.__? Explain.

*More accurately it could be stated in terms of mass; more, less, or the same mass.

[Compare element No. 1 vs. No. 2 (No. 1 is lighter); element No. 15 vs. No. 16 (No. 15 is lighter); element No. 18 vs. No. 19 (No. 18 is heavier); element No. 18 vs. No. 20 (same); element No. 33 vs. No. 35 (No. 33 is lighter).]

2) Atomic number, electron complement - What atomic number is assigned to the __th element in row __ and what is its electron complement? [Example: the 1st element in row 2 has an electron complement of 2, 1.] What atomic number is assigned to the __ th element of column __ and what is its electron complement? [Example: the 2nd element of column 7 has an electron complement of 2, 8, 7. What is the number of electrons in the outermost shell of the element with atomic No. 54? [Look in lower right portion of the Table; note that the element iodine has atomic No. 53 and its outermost shell has 7 electrons. Element No. 54 can be expected to have 8 outermost electrons...it is an inert element.]

3) Metallic, non-metallic, indeterminant, inert - Would element No.__ be more or less metallic than element No.__? [Example: element No. 3 on the left side of the Table is more metallic than any of those in the same row. Element No. 9 is more non-metallic than any of those in the same row. Element No. 10 is inert. Elements in column No. 4 are indeterminant; in some situations they can act like a metal, and in other situations a non-metal, because the electrons complements of their outermost shells are half filled.]

4) Reactivity of elements - In which parts of the Periodic Table would there be located those elements most likely to react or combine with each other: The left portion vs. the right portion of the Table? The upper portion vs. the lower portion of the Table? The central part of the Table? [In general, the elements on the left are most likely to react with those on the right except, of course, for the inert elements all of which are in column no. 8. Elements toward the right of the Table are the non-metals which acquire electrons to fill the electron complements of their outermost shells...such electrons may be readily provided by the elements toward the left of the Table, the metals. Elements of certain columns tend to react most readily with elements of certain other columns to form compounds; elements of column no. 1 combine readily with those of column no. 7, column no. 2 with column no. 6,

column no. 3 with column no. 5. These combinations are in accord with the rules for filling outer electron shells, however, there are a great many important modifications in advanced studies. It is very common for certain elements of column no. 5 to combine with an element of column no. 6 despite the designation of elements in these columns as non-metals. In the present instructional episode emphasize the most general rules, as given earlier.]

Summary Questions

The sketches of the Periodic Table, as used in a number of questions in the summary, can be very quickly copied on the chalkboard or overhead projector in free hand...each such sketch should have the title "Periodic Table" as a continual reminder to pupils, and they should have their own Tables in front of them. Do not push for too much in one session...be prepared to terminate the lesson for a day if signs of tension, confusion, or boredom are generally noticeable.

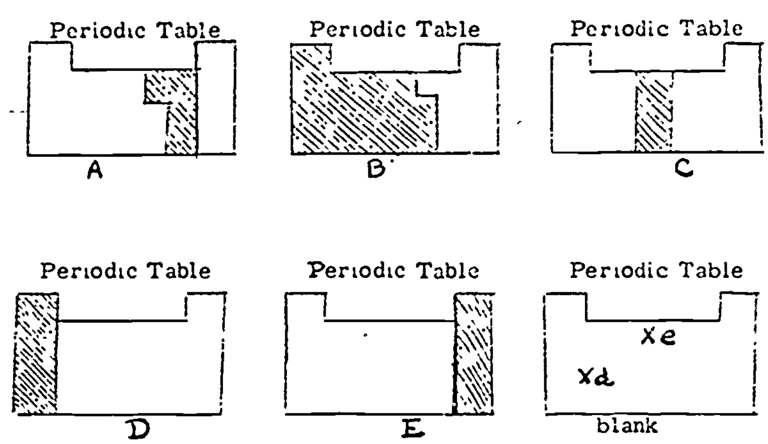
1) In what way are the elements in row __ all alike? [They all have the same number of electron shells.]

2) (a) How many electron shells does element No. 26 have? [4]

   (b) How many electron shells does element No. 21 have? [4]

   (c) How many electron shells does element No. 92 have? [7]

3) Predict the number of outer electrons of element No. 34. Explain. [According to the Periodic Table, element no. 33 has 5 electrons in its outer shell, and element no. 35 has 7 electrons in its outer shell. Element no. 34 which is between them can be expected to have 6 such electrons.]

4) 

(a) Most of the non-metals are located in the shaded part of which Periodic Table above? [A... elements that tend to be non-metals have more than 4 electrons in their outermost shell, therefore are located in columns nos. 5, 6, 7.]

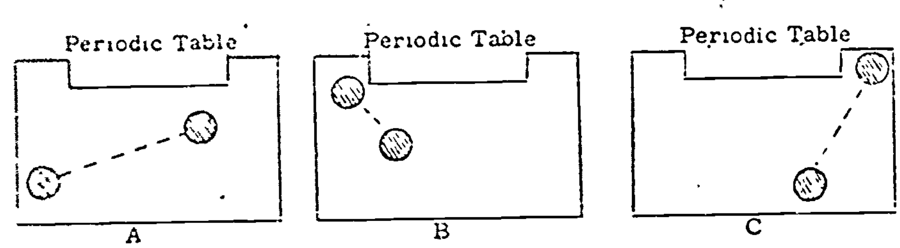
(b) The inert elements are located in the shaded part of which Periodic Table above? [E... elements that are inert have a complete electron complement in their outer shell.]

(c) The indeterminant elements are located in the shaded part of which Periodic Table above? Explain. [C... indeterminant elements can act like a metal or non-metal. Such elements have 4 electrons in their outermost shell, and therefore, are located in column no. 4.]

(d) There are several elements that are applied as common conductors of heat and electricity because they can be made into wire by heat, pressure and the action of tools. The neutral atoms of such elements have up to three electrons in their outermost shell. On a blank table (as above) indicate the approximate location of such elements by inscribing an "X". [Place the X toward the lower middle-left of the table. Here are located the well-known conductors such as copper, zinc, iron, silver... see X_d.]

(e) Make believe you are a scientist who needs an element that can act both like a metal and a non-metal and is light weight. On a blank table (as above) indicate the approximate location of such an element by inscribing an "X". [Place the X in the upper portion where the lighter elements are located and concomitahtly in the middle where the indeterminant elements are ' ated... see X_e.]

5)



(a) Each of two elements is represented by the symbol ⊘ . Which table shows the two elements positioned so that they would most likely form a compound? Explain. [A.... the positioning indicates a metal combining with a non-metal.]

(b) Which table shows the two elements in positions most unlikely to form a compound? Explain. [C.... the positioning indicates a non-metallic element and an inert element; the latter is not likely to enter into combination. The middle table indicates a combination of two metals which is possible, but not too common, therefore is not included in our studies.]

6)

(a) In Periodic Table A, draw a line from the element marked ⊗ to a circle ◯ which represents an element chemically most like ⊗ . Explain. [The line should be drawn vertically downward. Elements in the same column of the Periodic Table tend to have similar chemical characteristics because they have the same number of electrons in their outermost shell.]

(b) In Periodic Table B, draw a line from the element marked ⊗ to the circle ◯ that represents an element most likely to react or combine with ⊗ . Explain. [The line should be drawn toward the upper right or "two o'clock." The element directly to the right is fairly similar with a slightly greater number of outer electrons and is not likely to combine in a strong manner. The element to the far right is inert. The element in the same column has similar chemical properties. Element ⊗ appears to be a heavy metal, and could be expected to combine with a non-metal as in the upper right. Why? Metals tend to give up their outer electrons (1, 2, or 3 electrons) to non-metals which acquire or share electrons to complete the electron complement of their outer shells (5 or more electrons).]

New Vocabulary

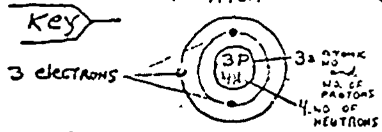
combine, combination
Periodic Table of the Elements
react, reaction

A PERIODIC TABLE OF SOME ELEMENTS

Teachers' copy

Key

DRAWING OF LITHIUM ATOM ($^{7}_{3}Li$). atomic mass; atomic number



Shells	ONE	TWO	THREE	FOUR	FIVE	SIX	SEVEN	EIGHT
1 SHELL	1 H 1 HYDROGEN	COLUMN NUMBER IS EQUAL TO THE NUMBER OF ELECTRONS USUALLY PRESENT IN OUTERMOST SHELL, OF A NEUTRAL ATOM						2 4 He 2 HELIUM
2 SHELLS	2,1 7 Li 3 LITHIUM	2,2 9 Be 4 BERYLLIUM	2,3 11 B 5 BORON	2,4 12 C 6 CARBON	2,5 14 N 7 NITROGEN	2,6 16 O 8 OXYGEN	2,7 19 F 9 FLUORINE	2,8 20 Ne 10 NEON
3 SHELLS	2,8,1 23 Na 11 SODIUM	2,8,2 24 Mg 12 MAGNESIUM	2,8,3 27 Al 13 ALUMINUM	2,8,4 28 Si 14 SILICON	2,8,5 31 P 15 PHOSPHORUS	2,8,6 32 S 16 SULFUR	2,8,7 35 Cl 17 CHLORINE	2,8,8 40 Ar 18 ARGON
4 SHELLS	2,8,8,1 39 K 19 POTASSIUM	2,8,8,2 40 Ca 20 CALCIUM	52 CHROMIUM 24 → 56 IRON 26 → 59 COBALT 27	59 NICKEL 28; 64 COPPER 29; 65 ZINC 30	2,8,18,5 75 As 33 ARSENIC		2,8,18,7 80 Br 35 BROMINE	2,8,18,8 84 Kr 36 KRYPTON
5 SHELLS	108 SILVER 47 → 112 CADMIUM 48 →			2,8,18,18,4 119 Sn 50 TIN			2,8,18,18,7 127 I 53 IODINE	
6 SHELLS	195 PLATINUM 78 → 197 GOLD 79 → 201 MERCURY 80 →			2,8,18,32,18,4 207 Pb 82 LEAD				2,8,18,32,18,8 222 Rn 86 RADON
7 SHELLS		226 Ra 88 RADIUM				238 U 92 URANIUM		

A PERIODIC TABLE OF SOME ELEMENTS

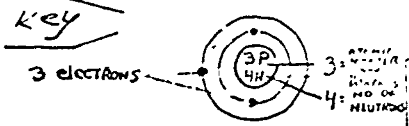
PUPILS COPY

DRAWING OF LITHIUM ($^{7}_{3}Li$) ATOM

ATOMIC MASS

ATOMIC NUMBER

KEY



COLUMNS NO = NUMBER OF ELECTRONS USUALLY PRESENT IN OUTERMOST SHELL OF A NEUTRAL ATOM

	ONE	TWO	THREE	FOUR	FIVE	SIX	SEVEN	EIGHT
1 SHELL	1 1 H 1 HYDROGEN							2 4 He 2 HELIUM
2 SHELLS	2,1 7 Li 3 LITHIUM	BERYLLIUM	BORON	CARBON	NITROGEN	OXYGEN	FLUORINE	NEON
3 SHELLS	SODIUM	MAGNESIUM	ALUMINUM	SILICON	2,8,5 31 P 15 PHOSPHORUS	SULFUR	CHLORINE	ARGON
4 SHELLS	POTASSIUM	CALCIUM	52 CHROMIUM 24 ⟶ 56 IRON 26 ⟶ 59 COBALT 27	59 NICKEL 28 ⟶ 64 COPPER 29 ⟶ 65 ZINC 30	2,8,18,5 75 As 33 ARSENIC		2,8,18,7 80 Br 35 BROMINE	2,8,18,8 84 Kr 36 KRYPTON
5 SHELLS	108 SILVER 47 ⟶ 112 CADMIUM 48 ⟶			2,8,18,18,4 119 Sn 50 TIN			2,8,18,18,7 127 I 53 IODINE	
6 SHELLS	195 PLATINUM 78 ⟶ 197 GOLD 79 ⟶ 201 MERCURY 80			207 Pb 82 LEAD				222 Rn 86 RADON
7 SHELLS		226 Ra 88 RADIUM				238 U 92 URANIUM		

APPENDIX D

Conversion Tables of IQs to T-Scores

Appendix D, Table No. 1

Conversion Table

Deviation IQs to T-Scores

Middle Elementary Experimental Classes, N = 57

DIQ	f	T-Scores	DIQ	f	T-Scores
123	1	73	98	1	46
120	1	69	97	2	46
116	1	67	96	1	45
115	2	64	95	3	44
113	3	62	94	1	43
111	2	60	93	3	42
109	3	58	89	2	40
107	7	55	88	2	39
106	1	53	87	1	37
105	1	53	85	1	36
104	2	52	83	1	35
102	3	51	80	1	34
101	4	49	79	1	32
100	2	48	77	1	30
99	2	47	70	1	26

Appendix D, Table No. 2

Conversion Table

Deviation IQs to T-Scores

Middle Elementary Reference*("Control") Classes, N = 56

DIQ	f	T-Scores	DIQ	f	T-Scores
122	1	73	99	3	50
119	1	69	98	2	49
117	1	66	97	6	47
115	2	64	95	3	45
113	1	62	93	4	43
112	2	61	91	2	41
111	4	59	89	2	40
109	3	57	88	2	38
104	2	55	85	1	37
103	1	54	83	1	35
102	3	53	81	1	34
101	4	52	79	2	31
100	1	51	75	1	26

*T-scores from reference classes IQs were not applied directly in testing hypotheses.

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Appendix D, Table No. 3

Conversion Table

Deviation IQs to T-Scores

Pre-Secondary Reference* ("Control") Classes, N = 54

DIQ	f	T-Scores	DIQ	f	T-Scores
127	1	73	101	1	45
122	1	69	100	1	45
118	2	65	99	1	44
117	3	62	98	1	44
116	1	60	97	2	43
114	3	59	96	4	41
113	1	57	95	1	39
112	5	56	94	1	39
110	1	54	92	2	37
109	3	53	91	1	36
108	5	51	90	1	34
107	2	50	88	1	33
106	2	49	85	1	30
104	3	47	80	1	26
102	2	46			

*T-scores from reference classes IQs were not applied directly in testing hypotheses.

Appendix D, Table No. 4

Conversion Table

Deviation IQs to T-Scores

Pre-Secondary Experimental Classes, N = 59

DIQ	f	T-Scores	DIQ	f	T-Scores
118	3	69	101	3	46
117	1	65	100	2	45
116	2	63	98	2	44
115	2	61	97	1	43
114	9	58	96	3	42
112	3	54	95	1	41
111	1	53	94	1	40
110	1	53	93	3	39
109	1	53	91	1	37
108	3	52	90	2	36
107	3	50	89	1	34
106	2	49	88	1	32
105	2	48	87	1	30
104	2	48	86	1	26
102	1	47			

Appendix D, Table No. 5

Conversion Table

Deviation IQs to T-Scores

Hypotheses Nos. 9a, 9b, 11a, 11b
Middle Elementary Boys$_x$, N = 30

DIQ	f	T-Scores	DIQ	f	T-Scores
123	1	71	97	2	46
120	1	66	95	3	44
113	3	61	93	1	42
109	1	59	87	1	40
107	5	55	85	1	39
106	1	52	83	1	38
104	2	51	79	1	36
102	1	50	77	1	33
101	1	49	70	1	28
99	2	48			

Appendix D, Table No. 6

Conversion Table

Hypotheses Nos. 10a, 10b, 12a, 12b
Middle Elementary Girls$_x$, N = 27

DIQ	f	T-Scores	DIQ	f	T-Scores
116	1	70	100	2	47
115	2	64	98	1	46
111	2	60	96	1	45
109	2	57	93	3	42
107	2	55	89	2	39
105	1	53	88	2	35
102	2	52	80	1	29
101	3	50			

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Appendix D, Table No. 7

Conversion Table

Deviation IQs to T-Scores

Hypotheses Nos. 13a, 13b, 15a, 15b
Pre-Secondary Boys$_x$, N = 29

DIQ	f	T-Scores	DIQ	f	T-Scores
118	2	68	104	1	48
117	1	63	102	1	47
116	1	61	101	1	46
115	1	60	97	1	45
114	4	57	96	2	44
112	1	54	94	1	42
111	1	53	93	2	40
110	1	52	90	1	38
109	1	51	89	1	36
108	1	50	88	1	33
107	1	50	86	1	28
105	1	49			

Appendix D, Table No. 8

Conversion Table.

Deviation IQs to T-Scores

Hypotheses Nos. 14a, 14b, 16a, 16b
Pre-Secondary Girls$_x$, N = 30

DIQ	f	T-Scores	DIQ	f	T-Scores
118	1	71	101	2	46
116	1	66	100	2	44
115	1	63	98	2	42
114	5	59	96	1	40
112	2	55	95	1	39
108	2	53	93	1	38
107	2	51	91	1	36
106	2	50	90	1	33
105	1	48	87	1	28
104	1	47			

APPENDIX E

The Measurement Instrument

TEST OF PUPIL'S ATTAINMENT

AFTER CERTAIN INSTRUCTIONAL EPISODES

LEADING TO AND PERTAINING TO THE

PLANETARY ATOMIC MODEL

An investigation in elementary science curriculum employing a major conceptual schemes approach.

by S. Harvey Steinberg

PRE - instructional form, administered_______________19__

POST - instructional form, administered_______________19__

X R Grade level_______________

Name of Pupil_________________________ BOY GIRL

Teacher's Name_________________________School_____________

DIRECTIONS FOR TEST ADMINISTRATION

1. Read the directions on the first page of the test booklet to the pupils.

2. Read each question aloud as many times as needed for each pupil to mark an answer to each question. The pupils should circle the letter of the best of four answers. They can use pen or pencil. Move around the room to ascertain that all pupils are working.

3. Space the seating of the pupils to insure that each does his own work. Encourage them to work hard even though some or nearly all of the questions are unfamiliar. Some classes will be taking the test a second time without benefit of formal in truction on the material. Ask them to do their best.

4. The PRE and the POST form are each given in two sittings. Each sitting will take at least 30 minutes (more likely 45 minutes), but time should not be a factor in completing the test. The first sitting of each of the PRE and POST forms ends with question no. 11.1.

5. To help dissipate the effects of fatigue, the class should, for one minute during each sitting, stand up, exercise, wiggle, talk, etc., then promptly go back to the task. Test papers should be closed during the break.

6. The pages of each booklet of the PRE form are in the same partially randomized order. The first sitting of both the PRE and POST forms of the test ends at question no. 11.1 and the second sitting begins at question no. 11.2.

(continued)

SECOND SITTING, PRE AND POST FORMS

7. Beginning at the second sitting (question no. 11.2) of both the PRE and POST form, two tables must be issued to each pupil. The teacher is to describe the use of each table upon distribution; tell the pupils only the following:

(TABLE OF 20 ELEMENTS)

a) "This sheet (show pupils...ask them to look at their table of 20 elements) is a table of the first 20 elements and their basic atomic parts."

(PERIODIC TABLE)

b) "This sheet (show pupils...ask them to look at their Periodic Table) is a Periodic Table of some of the elements. It is made in such a way that a relation is shown between an atom's electron shells and the number of electrons in the outermost shell. I will give you time to look over both tables. I cannot tell you how they are used, but I will tell you when they are used."

(TEACHER LETS PUPILS PERUSE TABLES, THEN SAYS:)

c) "Many of the questions in this part (second sitting) of the test state that The Pupil May Use the Tables or The Pupil Uses Tables. I will tell you on which questions either of these statements appears, but you will have to decide which table is best suited to help answer the question."

For each such question tell the pupils before reading the question that the tables can or may be used, and remind them again, a minute or so before going on to the next question.

Pupils who have not been taught how to use the tables may seem upset. Assure them that their "mark" in science will not be affected, but they will be expected to try hard on all questions.

It is important in the investigation that the directions for administering the test be implemented as exactly as possible. Your time and attention to these det ls is very much appreciated.

DIRECTIONS FOR PUPILS

PRE - FORM

1. The purpose of this test is to find out what you may know about certain parts of science. Try your best on every question.

2. There are probably many questions which ask about things that are new to you. Some may be fun to think about even if you are not sure of the answer. Try hard on all questions.

3. Each question has four answers, but only one is the best answer. Put a circle around the letter of the best answer only. Do every question.

4. The test will be given in two parts. At the start of the second part, you will be given two charts or tables. If you know how, the charts can help answer questions marked "PUPIL USES TABLES", or "PUPIL MAY USE TABLES".

5. Your teacher will read each question slowly. You should read along with your teacher. If you need more time, or need a question read again, ask you teacher.

DIRECTIONS FOR PUPILS

POST - FORM

1. The purpose of this test is to find out what you may have learned in science over the past few weeks. Don't be upset if you are not sure about an answer, but try your best on every question.

2. Each question has four answers, but only one is the best answer. Put a circle around the letter of the best answer only. Do every question.

3. The test will be given in two parts. At the start of the second part, you will be given two charts or tables. The charts can help you answer the questions marked "PUPIL USES TABLES", or "PUPIL MAY USE TABLES".

4. Your teacher will read each question slowly. You should read along with your teacher. If you need more time, or need a question read again, ask your teacher.

Episode No. 1

Inferential (background)

1.1 Why can a sponge soak up a lot of water?

A) Because sponges can bend when wet.
B) Because some kinds of sponges grow in water.
C) Because sponges have many open spaces.
D) Because sponges need water.

Episode No. 2

Inferential (background)

2.1 When a substance changes from a liquid to a gas, what happens to its molecules?

A) The molecules are destroyed.
B) The molecules get smaller.
C) The molecules get closer to each other.
D) The molecules move apart from each other.

Episode No. 3

Conceptual - Inferential (background)

3.1 The smell from perfume in a dish most easily spreads through a room when,

A) ice is put in the dish.
B) the room is made warmer.
C) the room is darkened.
D) the room is made colder.

3.2 Oil flows easier in hot weather because;

A) the oil molecules are far apart.
B) the oil molecules dry fast.
C) the oil molecules are close together
D) the oil molecules dry slow.

ERIC

Episode No. 4

Factual - Conceptual - Inferential (background)

4.1 A child takes a cold soft drink can from the refrigerator. He leaves it unopened. When he returns a few minutes later, he finds moisture on the can. How did the moisture get there?

A) Water from the air changes to a gas when it strikes the warm can.
B) The can leaked from around the top edge. It dripped down the side of the can.
C) Water molecules from the air collect on the can because they lost their heat to the cold can.
D) Heat from the can makes air molecules condense upon it.

Episode No. 5

Inferential (background)

5.1 A child tries to guess what is in a box. Of what can he be directly sure, without opening it?

A) What is in it.
B) If it has a living thing in it.
C) If it has a non-living thing in it.
D) The many kinds of things that cannot be in it.

Episode No. 5

Inferential (background)

5.2 Pretend each of the things listed has the same weight. Which one takes up the most space or volume?

A) A coin.
B) A new bar of soap.
C) A 10¢ chocolate bar.
D) A balloon floating in air.

5.3 Pretend each of the things listed has the same weight. Which one has the most density?

A) A coin.
B) A new bar of soap.
C) A 10¢ chocolate bar.
D) A balloon floating in air.

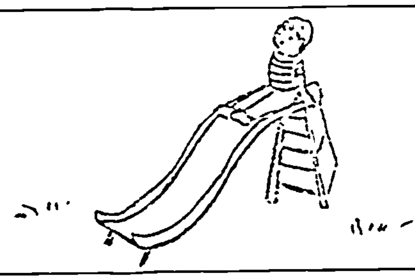
Episode No. 6

Factual - Conceptual - Inferential (background)

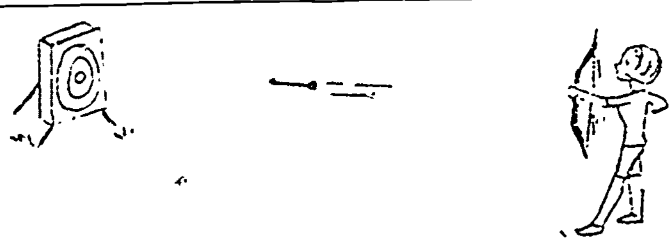
6.1 In which drawing does it show that work is being done?

A)

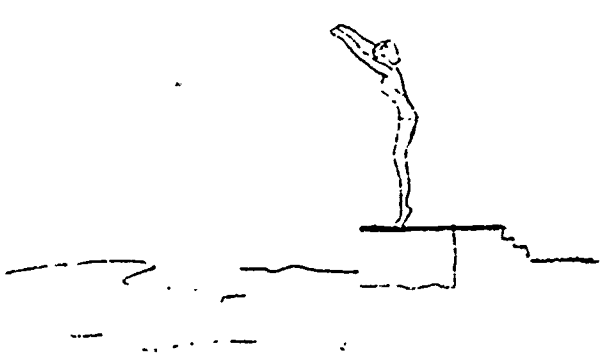
B)



C)

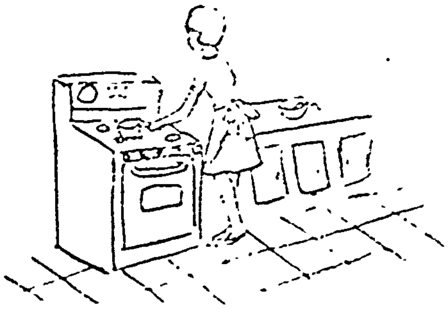


D)

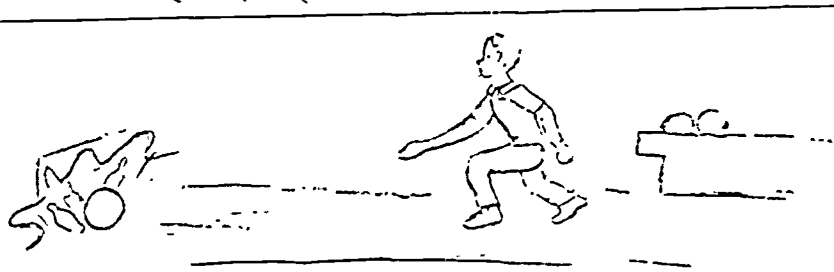


6.2 In which drawing is the <u>most</u> work being done?

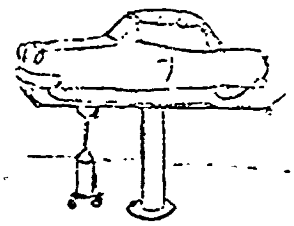
A)



B

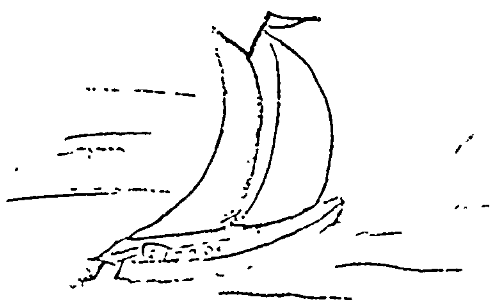


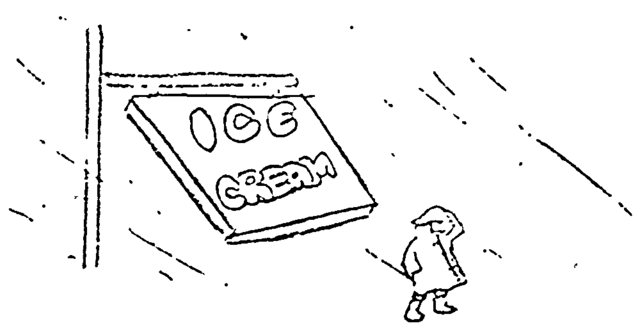
C)

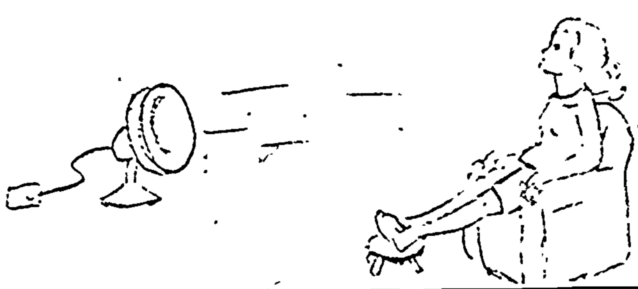


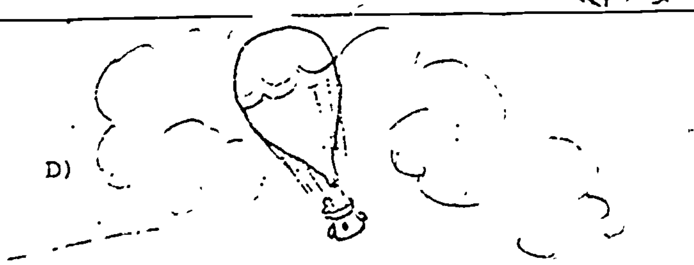
D)

6.3 Which drawing shows one kind of work being changed to another kind of work?

A) 

B) 

C) 

D) 

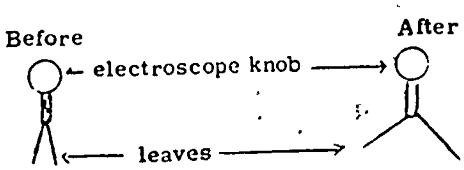
Episode No. 7

Factual - Conceptual - (background)

7.1 To add electric charges, or to take away electric charges,

A) work must always be done.
B) a switch must always be turned on.
C) a switch must always be turned off.
D) always use an electroscope.

7.2



Which particles could make the leaves of the electroscope act as the drawing shows?

KEY
Positive charged electrical particle = (+)
Negative charged electrical particle = (-)

A) (+) (-)
B) (-) (+)
C) (+) (+) or (-) (-)
D) (+) (-) (+) (-)

7.3 Negative electric charges show up on an ebony rod when it is rubbed with fur. From where do the negative charges come?

A) The smallest parts of the fur.
B) Batteries inside the ebony rod.
C) The smallest parts of the ebony rod.
D) Magnets inside the ebony rod.

7.4 Which chain of electrical particles would need the most work or energy to be broken apart?

KEY
Positive charged electrical particle = (+)
Negative charged electrical particle = (-)
Neutral particle = ○

A) (+)(+)(+)(+)
B) ○(+)(+)○
C) (-)(-)(-)(-)
D) (+)(-)(+)(-)

Either

THE MEASUREMENT INSTRUMENT

The post-instructional form of the test appears in this appendix. Pages in the pre-instructional form were in a partly randomized order. Included here are directions for teachers and pupils on the pre and post instructional forms.

The reference tables required for Part II of both forms of the test are virtually identical to those recorded in Appendix C, Sequence of Instructional Episodes; see page 5 episode no. 11 for the chart entitled The First 20 Elements, and see the final page of episode no. 14 for pupils' copy of A Periodic Table of Some Elements.

Following the administration of the post-instructional test, the investigator discovered that one question, no. 7.4, had an ambiguity in content. A pupil who knew only that it requires work to overcome electrostatic attraction between bodies would be likely to select answer D. He would reject answer A reasoning that protons repulse each other. On the other hand, a pupil who understood the preceding, but also knew that great "forces" hold protons together in atomic nuclei would select answer A, reasoning that much work would be required to separate protons united as such. In scoring, either answer A or D was counted as a correct answer.

Episode No. 8

Factual - Conceptual - Inferential (background)

8.1 A[illegible] are thought to be partly made up of:

A) Negative charged particles and positive charged particles.
B) Neutral molecules
C) Negative charged molecules and positive charged molecules.
D) Positive electrical molecules

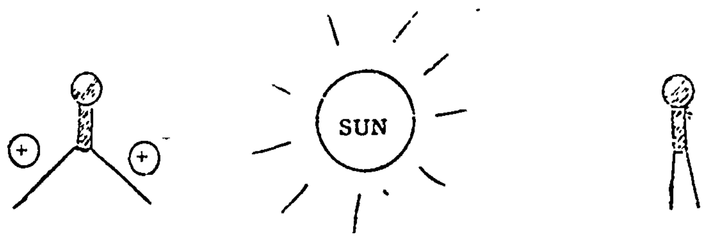
8.3 If we rub a substance, what part of its atoms is most likely to be moved?

A) protons
B) neutrons
C) electrons
D) nuclei

8.4 When an atom loses electrons it:

A) becomes more positively (+) charged.
B) becomes more negatively (-) charged.
C) becomes neutral.
D) is destroyed.

8.5



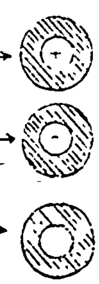
In sunlight the leaves of a positively charged electroscope go down because energy from the sun gives some of the air around the electroscope an electric charge. Which air particles make the leaves go down?

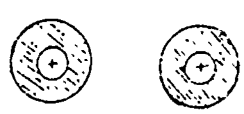
KEY

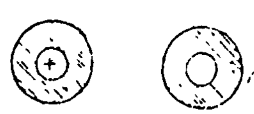
air particle with positive charge →

air particle with negative charge →

air particle with no charge →



A) 

B) 

C) 

D) 

Episode No. 9

Factual - Conceptual

9.1 Scientists tell us that about 100 elements make-up all the things of the world. How do each of the elements differ from each other?

A) All elements are alike except for their names.
B) Each element has its own kind of atom.
C) All elements are alike except for their color.
D) Each element is a different mixture of compounds.

9.2 What is the tiniest part of an element which is exactly like the element?

A) a compound
B) a mixture
C) a molecule
D) an atom

9.3 What is the tiniest part of a compound which is exactly like the compound?

A) A molecule
B) An atom
C) A mixture
D) An element

9.4 When the element hydrogen and the element oxygen are joined in the right way, they form water. Water is called:

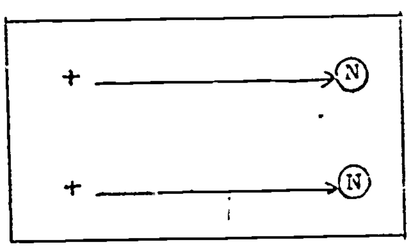
A) A mixture
B) An element
C) A mixture of compounds
D) A compound

Episode No. 10

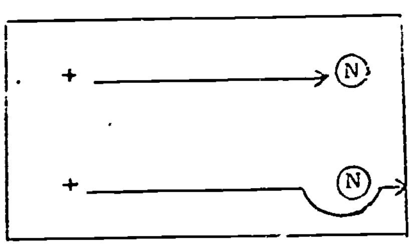
Factual - Conceptual - Inferential

10.1 A scientist shoots high speed positive charges, + $\longrightarrow$, at atomic nuclei, (N). Which drawing shows the most likely result?

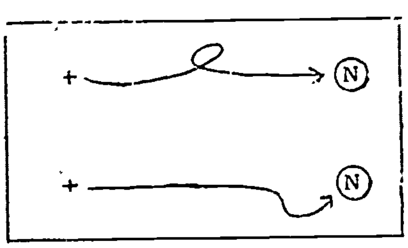
A)



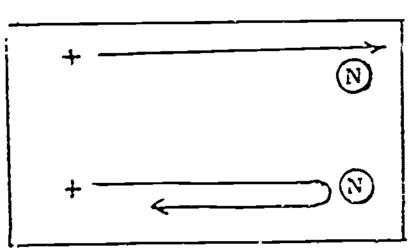
B)



C)



D)



Episode No. 11

Factual - Conceptual - Inferential

11.1 Which one of these parts of an atom is thought to have the least mass ("weight")?

A) neutron

B) electron

C) positive charge

D) proton

END FIRST HALF OF TEST HERE

ERIC

BEGIN SECOND HALF OF TEST HERE.

EACH PUPIL RECEIVES TWO TABLES.

11.2 (PUPIL MAY USE TABLES)

The atomic number of an element is always the same as its:

A) atomic mass ("weight").
B) number of neutrons.
C) number of protons.
D) number of electron shells.

11.3 What is the atomic number of the element with 26 protons and an atomic mass ("weight") of 56?

A) 56
B) 82
C) 30
D) 26

ERIC

11.4 (PUPIL MAY USE TABLES)

An element with 15 protons and an atomic mass ("weight") of 31 has how many neutrons?

A) 31

B) 15

C) 16

D) 46

11.5 (PUPIL USES TABLES)

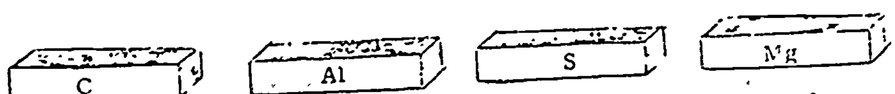
In the first 20 elements, which elements have all their electron shells filled?

A) helium (He), neon (Ne), argon (Ar)
B) helium (He), oxygen (O), neon (Ne)
C) hydrogen (H) helium (He), beryllium (Be)
D) beryllium (Be), oxygen (O), argon (Ar)

ERIC

11.6 (PUPIL USES TABLES)

Equal sized boxes are completely filled with certain elements; as pictured.



box of carbon box of aluminum box of sulfur box of magnesium

Which one weighs the most?

A) sulfur (S)

B) aluminum (Al)

C) carbon (C)

D) magnesium (Mg)

11.7 (PUPIL USES TABLES)

Which one of these elements has the most neutrons?

A) No. 20

B) No. 19

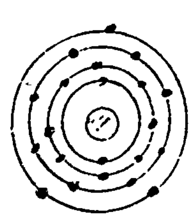
C) No. 18

D) No. 17

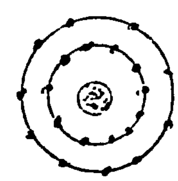
11.8 (PUPIL USES TABLES)

A drawing of an atom of element No. 21 would be like which one of these?

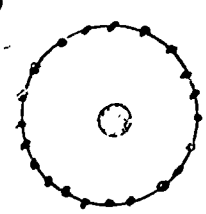
A)



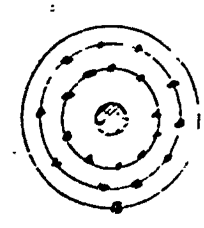
C)



B)



D)



Episode No. 12

Factual - Conceptual

12.1 An inert element is NOT usually active because its outer electron shell:

A) has fewer than 4 electrons.

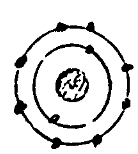
B) is complete.

C) has 4 electrons

D) has no electrons.

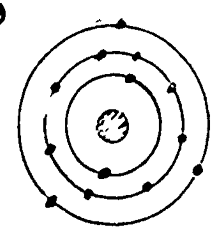
12.2 Which one of these elements would most easily lose outer electrons?

A)



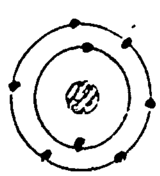
neon (Ne)

C)



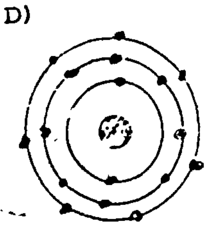
aluminum (Al)

B)



oxygen (O)

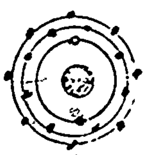
D)



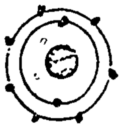
chlorine (Cl)

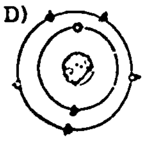
12.3 (PUPIL MAY USE TABLES)

Which one of these elements is most likely to act as a metal?

A) 
argon (Ar)
atomic no. 18

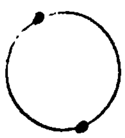
C) 
hydrogen (H)
atomic no. 1

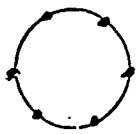
B) 
fluorine (F)
atomic no. 9

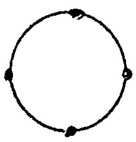
D) 
nitrogen (N)
atomic no. 7

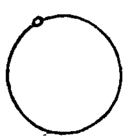
12.4 (PUPIL MAY USE TABLES)

Some elements can act like metals or can act like non-metals. Which drawing best shows the outer electron shell of an element most likely to act this way?

A) 

C) 

B) 

D) 

12.5 (PUPIL USES TABLES)

The element sodium (Na) and the element fluorine (F) can form the compound sodium fluoride (NaF). Which sentence best explains how the compound is formed?

A) Fluorine's outer electron fills sodium's outer shell.
B) Sodium loses all its electrons.
C) Sodium's outer electron fills fluorine's outer shell.
D) Fluorine loses all its electrons.

Episode No. 13

Factual - Conceptual

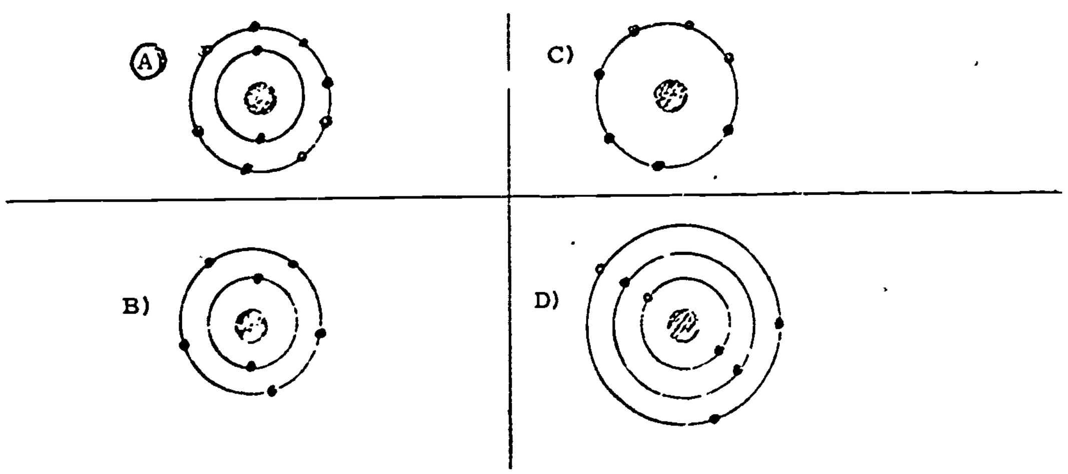
13.1 Charged atoms have:

A) lost neutrons.
B) gained electrons or lost electrons.
C) gained neutrons.
D) gained neutrons and lost protons.

13.2 (PUPIL MAY USE TABLES)

Which one of these drawings shows a charged atom of nitrogen (N)?

atomic No. = 7



13.3 (PUPIL USES TABLES)

The ocean has in it the compound magnesium chloride . The elements magnesium (Mg) atomic No. = 12, and chlorine (Cl) atomic No. = 17 are separated by electrolysis. At which poles are these elements collected during electrolysis?

POSITIVE POLE = +

NEGATIVE POLE = −

A) chlorine at − magnesium at +

B) chlorine at + magnesium at −

C) chlorine at − magnesium at −

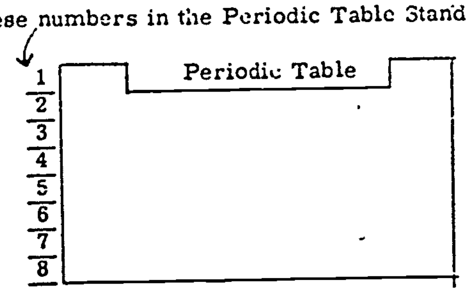
D) chlorine at + magnesium at +

Episode No. 14

Factual - Conceptual - Inferential

14.1 (PUPIL USES TABLE)

What do these numbers in the Periodic Table Stand for?

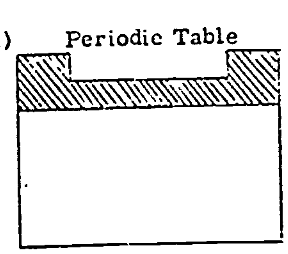


A) The number of electrons in the atom.
B) The number of protons.
C) The atomic number.
D) The number of electron shells.

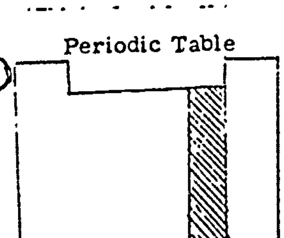
14.2 (PUPIL USES TABLE)

In the shaded part of which Periodic Table drawing do the elements act most like each other?

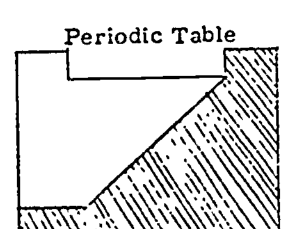
A)



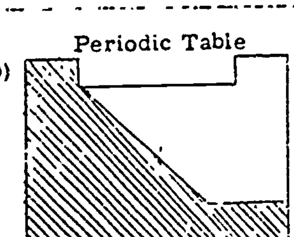
B)



C)

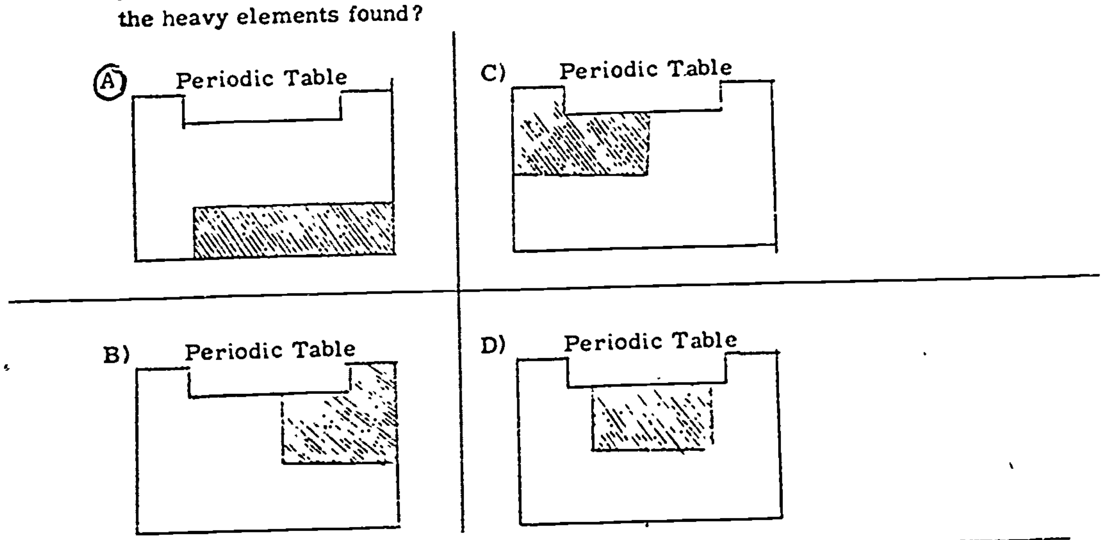


D)



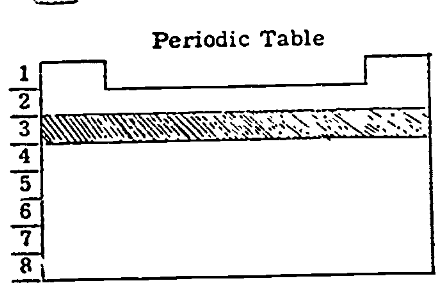
14.3 (PUPIL MAY USE TABLE)

In the shaded part of which Periodic Table drawing are some of the heavy elements found?



14.4 (PUPIL MAY USE TABLE)

What is the smallest number of total electrons that an atom can have in the shaded part of the Periodic Table in the drawing?

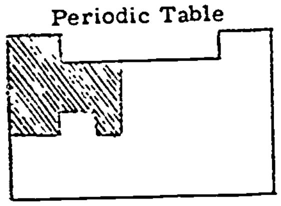


A) 3
B) 16
C) 11
D) 6

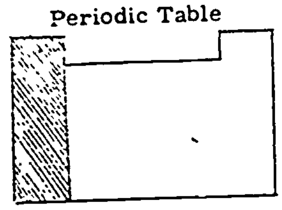
14 5 (PUPIL MAY USE TABLE)

In the shaded part of which Periodic Table drawing would some non-metallic elements be found?

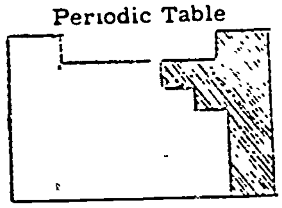
A) Periodic Table



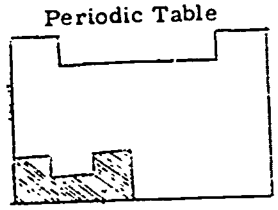
C) Periodic Table



(B) Periodic Table

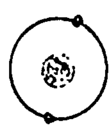


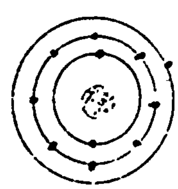
D) Periodic Table

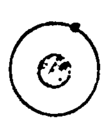


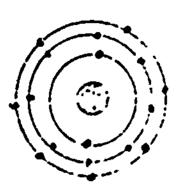
14.6 (PUPIL MAY USE TABLES)

Pretend you are a scientist looking for a very light weight element that does NOT easily form compounds. Which one of these would you choose?

(A)  atomic no. 2

C)  atomic no. 11

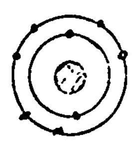
B)  atomic no. 1

D)  atomic no. 17

14.7 (PUPIL MAY USE TABLES)

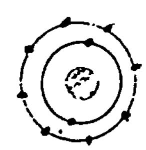
Pretend you are a scientist looking for an element that is very likely to form compounds with either metals or non-metals. Which one of these would you choose?

A)



atomic no. 8

C)

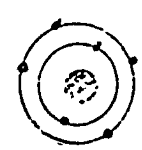


atomic no. 10

B)

atomic no. 1

D)



atomic no. 6

APPENDIX F

Experimental Run: Number Correct Per Test Item for Estimating Reliability.

Appendix F, Table No. 1

Experimental Run: Number Correct Per Test Item for Estimating Reliability*

Item Designation on Test	No. Correct	Item Designation on Test	No. Correct
1.1	111	10.1	95
2.1	88	11.1	65
3.1	96	11.2	93
3.2	56	11.3	48
4.1	77	11.4	101
5.1	78	11.5	89
5.2	95	11.6	104
5.3	64	11.7	94
6.1	100	11.8	100
6.2	61	12.1	93
6.3	73	12.2	104
7.1	86	12.3	92
7.2	69	12.4	74
7.3	87	12.5	59
7.4	95	13.1	59
8.1	67	13.2	22
8.2	70	13.3	56
8.3	81	14.1	102
8.4	55	14.2	76
8.5	70	14.3	58
9.1	54	14.4	17
9.2	78	14.5	77
9.3	61	14.6	50
9.4	65	14.7	62
			Sum = 3627

*These scores were taken from the post-instructional tests of the 116 pupils of the experimental classes. Additional data for estimating the coefficient of reliability for experimental and pilot classes are reported in Table XLIV.

ERIC

VITA

S.(amuel) Harvey Steinberg was born in Syracuse, New York, February 1, 1928. He is the only surviving child of Rose I. Chadwick Steinberg and Nathan Steinberg. He was educated in Syracuse public schools, graduating from Central High in January 1946. During two periods from 1946 through 1951, he served a total of 33 months enlisted in the U. S. Marine Corps. He entered Syracuse University in 1948 and received a Bachelor of Science in Combined Science degree in 1953. In 1954 he received the Master of Science in Science Education degree from Syracuse University. From 1954 to 1956 he was chairman of the science department at New York Mills, New York High School. In 1955 he was awarded a New York State War Service scholarship and thereby continued advanced studies in science education. From 1956 to 1961 he taught at Syracuse Central Technical High School and was chairman of the academic science department for three years. He was married to the former Jean Marie Farrington on October 10, 1959. Since September 1961 he has been an assistant professor at State University College, Cortland, New York.

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