Base your answers to questions 1 and 2 on the passage below and on your knowledge of Earth Science.

**Cosmic Microwave Background Radiation**

In the 1920s, Edwin Hubble's discovery of a pattern in the red shift of light from galaxies moving away from Earth led to the theory of an expanding universe. This expansion implies that the universe was smaller, denser, and hotter in the past. In the 1940s, scientists predicted that heat (identified as cosmic microwave background radiation) left over from the Big Bang would fill the universe. In the 1960s, satellite probes found that cosmic microwave background radiation fills the universe uniformly in every direction, and indicated a temperature of about 3 kelvins (K). This radiation has been cooling as the universe has been expanding.

1. Which graph best shows the relationship of the size of the universe to the temperature indicated by the cosmic microwave background radiation?

   - A) 1.0 billion years ago
   - B) 3.3 billion years ago
   - C) 8.2 billion years ago
   - D) 13.7 billion years ago

2. Scientists infer that the universe began approximately

   - A) 1.0 billion years ago
   - B) 3.3 billion years ago
   - C) 8.2 billion years ago
   - D) 13.7 billion years ago

3. Which statement best describes galaxies?

   - A) They are similar in size to the solar system.
   - B) They contain only one star but hundreds of planets.
   - C) They may contain a few hundred stars in a space slightly larger than the solar system.
   - D) They may contain billions of stars in a space much larger than our solar system.
Base your answers to questions 4 through 7 on the table below, which shows eight inferred stages describing the formation of the universe from its beginning to the present time.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description of the Universe</th>
<th>Average Temperature of the Universe ($^\circ$C)</th>
<th>Time From the Beginning of Universe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>the size of an atom</td>
<td>?</td>
<td>0 second</td>
</tr>
<tr>
<td>2</td>
<td>the size of a grapefruit</td>
<td>?</td>
<td>$10^{-43}$ second</td>
</tr>
<tr>
<td>3</td>
<td>&quot;hot soup&quot; of electrons</td>
<td>$10^{27}$</td>
<td>$10^{-32}$ second</td>
</tr>
<tr>
<td>4</td>
<td>Cooling allows protons and neutrons to form.</td>
<td>$10^{13}$</td>
<td>$10^{-9}$ second</td>
</tr>
<tr>
<td>5</td>
<td>still too hot to allow the forming of atoms</td>
<td>$10^8$</td>
<td>3 minutes</td>
</tr>
<tr>
<td>6</td>
<td>Electrons combine with protons and neutrons, forming hydrogen and helium atoms. Light emission begins.</td>
<td>10,000</td>
<td>300,000 years</td>
</tr>
<tr>
<td>7</td>
<td>Hydrogen and helium form giant clouds (nebulae) that will become galaxies. First stars form.</td>
<td>$-200$</td>
<td>1 billion years</td>
</tr>
<tr>
<td>8</td>
<td>Galaxy clusters form and first stars die. Heavy elements are thrown into space, forming new stars and planets.</td>
<td>$-270$</td>
<td>13.7 billion years</td>
</tr>
</tbody>
</table>

4. According to this table, the average temperature of the universe since stage 3 has
   - A) decreased, only
   - B) increased, only
   - C) remained the same
   - D) increased, then decreased

5. What is the most appropriate title for this table?
   - A) The Big Bang Theory
   - B) The Theory of Plate Tectonics
   - C) The Law of Superposition
   - D) The Laws of Planetary Motion

6. Between which two stages did our solar system form?
   - A) 1 and 3
   - B) 3 and 5
   - C) 6 and 7
   - D) 7 and 8

7. How soon did protons and neutrons form after the beginning of the universe?
   - A) $10^{-43}$ second
   - B) $10^{-32}$ second
   - C) $10^{-6}$ second
   - D) 13.7 billion years

8. The major evidence supporting the "Big Bang" theory is
   - A) observations of supernova explosions.
   - B) the discovery of black holes.
   - C) observations that the Doppler red shift becomes greater as we look at more distant galaxies.
   - D) observations that most galaxies are rotating
9. The diagram below represents a side view of the Milky Way Galaxy.

At approximately which position is Earth's solar system located?
A) A  B) B  C) C  D) D

10. Cosmic background radiation provides direct evidence for the origin of
A) the universe
B) our solar system
C) Earth's ozone layer
D) Earth's earliest atmosphere

11. Compared to light from a stationary source at the same point, light from an object moving toward you is
A) brighter
B) bluer
C) redder
D) unchanged in both color and brightness

12. Most astronomers agree that at the present time universe is
A) contracting
B) expanding
C) staying the same size
D) expanding and contracting regularly

13. Which evidence best supports the Big Bang theory?
A) rate of rotation of the Sun
B) existence of cosmic background radiation
C) uniform radioactive decay of uranium-238
D) separation of Earth's interior into different layer

14. The red shift of visible light waves that is observed by astronomers on Earth is used to determine the
A) sizes of nearby galaxies
B) relative motions of distant galaxies
C) densities of the planets
D) rotation periods of the planets

15. Evidence that the universe is expanding is best provided by the
A) red shift in the light from distant galaxies
B) change in the swing direction of a Foucault pendulum on Earth
C) parallelism of Earth's axis in orbit
D) spiral shape of the Milky Way Galaxy

16. According to the big bang theory, the universe began as an explosion and is still expanding. This theory is supported by observations that the stellar spectra of distant galaxies show a
A) concentration in the yellow portion of the spectrum
B) concentration in the green portion of the spectrum
C) shift toward the blue end of the spectrum
D) shift toward the red end of the spectrum

17. In a Doppler red shift, the observed wavelengths of light from distant celestial objects appear closer to the red end of the spectrum than light from similar nearby celestial objects. The explanation for the red shift is that the universe is presently
A) contracting, only
B) expanding, only
C) remaining constant in size
D) alternating between contracting and expanding

18. The more that the spectral lines of a star are shifted to the red end of the spectrum
A) orbital velocities of stars are decreasing
B) Earth's atmosphere is warming
C) the Sun is cooling
D) the universe is expanding

19. Astronomers viewing light from distant galaxies observe a shift of spectral lines toward the red end of the visible spectrum. This shift provides evidence that
A) orbital velocities of stars are decreasing
B) Earth's atmosphere is warming
C) the Sun is cooling
D) the universe is expanding
20. Which evidence best supports the theory that the universe began with a massive explosion?

A) cosmic background radiation in space
B) parallelism of planetary axes
C) radioactive dating of Earth’s bedrock
D) life cycle of stars

21. According to astronomers, the age of the universe is estimated to be

A) 1.3 billion years  B) 4.6 billion years  C) 7.9 billion years  D) 13.8 billion years

22. The red shift of light from most galaxies is evidence that

A) most galaxies are moving away from Earth
B) a majority of stars in most galaxies are red giants
C) the light slows down as it nears Earth
D) red light travels faster than other colors of light

23. A light year is

A) the distance traveled by light in one year
B) the distance the Earth moves in one year
C) the time it takes light to go once around the Earth's orbit
D) the time it takes light to travel one year

24. Starlight from distant galaxies provides evidence that the universe is expanding because this starlight shows a shift in wavelength toward the

A) red-light end of the visible spectrum
B) blue-light end of the visible spectrum
C) ultraviolet-ray end of the electromagnetic spectrum
D) gamma-ray end of the electromagnetic spectrum

25. Which statement best describes the age of our solar system and the universe?

A) The universe is at least twice as old as our solar system.
B) Our solar system is at least twice as old as the universe.
C) Our solar system and the universe are estimated to be 5 billion years old.
D) Our solar system and the universe are estimated to be 10 billion years old.

26. The diagram below shows a standard spectrum compared to a spectrum produced from a distant star.

![Standard Spectrum and Spectrum from Distant Star]

Which conclusion can be made by comparing the standard spectrum to the spectrum produced from this distant star?

A) The star's spectral lines have shifted toward the ultraviolet end of the spectrum and the star is moving toward Earth.
B) The star's spectral lines have shifted toward the ultraviolet end of the spectrum and the star is moving away from Earth.
C) The star's spectral lines have shifted toward the infrared end of the spectrum and the star is moving toward Earth.
D) The star's spectral lines have shifted toward the infrared end of the spectrum and the star is moving away from Earth.

27. A star moving away from the Earth will have a spectrum containing

A) red shifted lines  B) blue shifted lines  C) unshifted lines  D) dim lines

28. Which sequence correctly lists the relative sizes from smallest to largest?

A) our solar system, universe, Milky Way Galaxy
B) our solar system, Milky Way Galaxy, universe
C) Milky Way Galaxy, our solar system, universe
D) Milky Way Galaxy, universe, our solar system
29. If we observe a Doppler blue shift from a star, the star must be
   A) relatively cool in temperature
   B) moving away from us
   C) moving toward us
   D) a blue star

30. The unit most used by astronomers to express the distances to other galaxies is
   A) miles
   B) kilometers
   C) astronomical unit (AU)
   D) Lightyears (LY)

31. The current temperature indicated by the cosmic microwave background radiation is
   A) higher than the temperature at which water boils
   B) between the temperature at which water boils and room temperature
   C) between room temperature and the temperature at which water freezes
   D) lower than the temperature at which water freezes

32. Which information best supports the inference that the universe began with an explosion?
   A) measurements of rates of decay using carbon-14
   B) measurements of cosmic background radiation
   C) calculations of the distance from the Sun to each asteroid in the asteroid belt
   D) calculations of the temperature and luminosity of stars

33. The explosion associated with the theory and the formation of the universe inferred to have occurred how many billion ago?
   A) less than 1
   B) 2.5
   C) 4.6
   D) over 10

34. Earth, the Sun, and billions of stars are contained within
   A) a single constellation
   B) the Milky Way galaxy
   C) the solar system
   D) a giant cloud of gas

35. Billions of stars in the same region of the universe are called
   A) solar systems
   B) asteroid belts
   C) constellations
   D) galaxies

36. The Sun revolves around the center of
   A) Polaris
   B) Aldebaran
   C) Earth
   D) the Milky Way Galaxy

37. A red shift in the light from very distant galaxies suggests that the universe is
   A) fixed and stationary
   B) moving randomly
   C) contracting
   D) expanding

38. The Sun's position in space is best described as the approximate center of
   A) a constellation
   B) the universe
   C) the Milky Way galaxy
   D) our solar system
39. Base your answer to the following question on the data table below and on your knowledge of Earth science. The data table lists four constellations in which star clusters are seen from Earth. A star cluster is a group of stars near each other in space. Stars in the same cluster move at the same velocity. The length of the arrows in the table represents the amount of redshift of two wavelengths of visible light emitted by these star clusters.

<table>
<thead>
<tr>
<th>Constellation in which star cluster is seen from Earth</th>
<th>Redshift of two wavelengths of light absorbed by calcium</th>
<th>Distance from Earth (billion light years)</th>
<th>Velocity of star cluster moving away from Earth (km/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ursa Major</td>
<td>Violet Red</td>
<td>1.0</td>
<td>15,000</td>
</tr>
<tr>
<td>Corona Borealis</td>
<td>Violet Red</td>
<td>1.4</td>
<td>22,000</td>
</tr>
<tr>
<td>Boötes</td>
<td>Violet Red</td>
<td>2.5</td>
<td>39,000</td>
</tr>
<tr>
<td>Hydra</td>
<td>Violet Red</td>
<td>4.0</td>
<td>61,000</td>
</tr>
</tbody>
</table>

Note: One light year is the distance light travels in one year.

Identify the name of the nuclear process that is primarily responsible for producing energy in stars.

40. A blue shift of the light from a star indicates that the star

A) will soon become a main sequence star
B) will soon become a giant star
C) is moving closer to Earth
D) is moving away from Earth

41. What does a red shift in light from distant celestial objects indicate to a scientist on Earth?

A) The gravitational force on Earth changes.
B) The universe appears to be expanding.
C) The Jovian planets are aligned with the Sun.
D) Galaxies are becoming more numerous.

42. The velocity of a star toward or away from the Earth can be determined by measuring the

A) color of the star
B) shift of its spectral lines
C) brightness of the star
D) its change in apparent size

43. Cosmic microwave background radiation is classified as a form of electromagnetic energy because it

A) travels in waves through space
B) moves faster than the speed of light
C) is visible to humans
D) moves due to particle collisions

44. When viewed from Earth, the light from very distant galaxies shows a red shift. This is evidence that these distant galaxies are

A) shifting to shorter wavelengths.
B) shifting to longer wavelengths.
C) appear blue.
D) appear red.

45. The Doppler effect predicts that light from a source moving away from Earth will be

A) shifted to shorter wavelengths.
B) shifted to longer wavelengths.
C) appear blue.
D) appear red.
46. Compared to Earth's solar system, the universe is inferred to be
   A) younger and larger
   B) younger and smaller
   C) older and larger
   D) older and smaller

47. Most scientists believe the Milky Way Galaxy is
   A) spherical in shape
   B) 4.6 billion years old
   C) composed of stars revolving around Earth
   D) one of billions of galaxies in the universe

48. Light from distant galaxies most likely shows a
   A) red shift, indicating that the universe is expanding
   B) red shift, indicating that the universe is contracting
   C) blue shift, indicating that the universe is expanding
   D) blue shift, indicating that the universe is contracting

49. What is the name usually given to the group of objects consisting of a sun and any planets, comets, and other objects that orbit it?
   A) a solar system
   B) a universe
   C) a galaxy
   D) an ecosystem

50. The redshift of light from distant galaxies provides evidence that the universe is
   A) shrinking, only
   B) expanding, only
   C) shrinking and expanding in a cyclic pattern
   D) remaining the same size

51. The diagram below represents the bright-line spectrum for an element.

   ![Spectrum Diagram]

   The spectrum of the same element observed in the light from a distant star is shown below.

   ![Spectrum Diagram]

   The shift in the spectral lines indicates that the star is moving
   A) toward Earth
   B) away from Earth
   C) in an elliptical orbit around the Sun
   D) in a circular orbit around the Sun

52. The diagram below shows the spectral lines for an element.

   ![Spectrum Diagram]

   Which diagram best represents the spectral lines of this element when its light is observed coming from a star that is moving away from Earth?
   A) ![Diagram A]
   B) ![Diagram B]
   C) ![Diagram C]
   D) ![Diagram D]
53. The diagram below represents the shape of the Milky Way Galaxy.

The Milky Way Galaxy is best described as

A) elliptical    B) irregular
C) circular
D) spiral

54. According to the Big Bang theory, which graph best represents the relationship between time and the size of the universe from the beginning of the universe to the present?
55. The diagram below represents the development of our universe from the time of the Big Bang until the present. Letter A indicates two celestial objects.

![Diagram of the universe](image)

The present-day celestial objects labeled A are best identified as:

A) asteroid belts  B) terrestrial planets  
C) **spiral galaxies**  D) eccentric comets

56. The symbols below represent the Milky Way galaxy, the solar system, the Sun, and the universe.

- = Milky Way Galaxy  
= Solar System  
= Sun  
= Universe

Which arrangement of symbols is most accurate?

A)  
B)  
C)  
D)  

57. Which celestial feature is largest in actual size?

A) the Moon  B) Jupiter  
C) the Sun  D) **the Milky Way**

58. The diagram below illustrates three stages of a current theory of the formation of the universe.

![Stages of the universe](image)

A major piece of scientific evidence supporting this theory is the fact that wavelengths of light from galaxies moving away from Earth in stage 3 are observed to be:

A) shorter than normal (a red shift)  
B) shorter than normal (a blue shift)  
C) **longer than normal (a red shift)**  
D) longer than normal (a blue shift)
59. The timeline below represents time from the present to 20 billion years ago. Letters A, B, C, and D represent specific times.

Which letter on the timeline best represents the time when scientists estimate that the Big Bang occurred?

A) A  B) B  C) C  D) D

60. According to Hubbell’s law more rapidly moving galaxies are now

A) further away from us  B) closer to us  C) accelerating rapidly  D) already contracting toward another big bang

61. In which list are celestial features correctly shown in order of increasing size?

A) galaxy → solar system → universe → planet  B) solar system → galaxy → planet → universe  C) planet → solar system → galaxy → universe  D) universe → galaxy → solar system → planet

62. The theory that the universe is expanding is supported by the

A) blue shift of light from distant galaxies  B) red shift of light from distant galaxies  C) nuclear fusion occurring in the Sun  D) radioactive decay occurring in the Sun

63. Fourteen billion years represents the approximate age of

A) Earth  B) Earth's Moon  C) our solar system  D) the universe

64. A major piece of evidence supporting the Big Bang theory is the observation that wavelengths of light from stars in distant galaxies show a

A) redshift, appearing to be shorter  B) redshift, appearing to be longer  C) blueshift, appearing to be shorter  D) blueshift, appearing to be longer

65. The photograph below shows a feature of the universe as seen through a telescope.

This feature is best identified as

A) a galaxy  B) a comet  C) an asteroid  D) a star

66. The Big Bang Theory, describing the creation of the universe, is most directly supported by the

A) redshift of light from distant galaxies  B) presence of volcanoes on Earth  C) apparent shape of star constellations  D) presence of craters on Earth's Moon

67. The Milky Way galaxy is best described as

A) nuclear decay of radioactive materials  B) nuclear fusion of radioactive materials  C) blue shift of light from distant galaxies  D) red shift of light from distant galaxies

68. The theory that the universe is expanding is supported by data from the

A) nuclear decay of radioactive materials  B) nuclear fusion of radioactive materials  C) blue shift of light from distant galaxies  D) red shift of light from distant galaxies
69. Which evidence best supports the theory that the universe was created by an explosion called the Big Bang?

A) impact craters found on Earth  
B) **cosmic background radiation**  
C) the different compositions of terrestrial and Jovian planets  
D) the blue shift of light from distant galaxies

70. The symbols below are used to represent different regions of space.

- Universe = 
- Earth = 
- Galaxy =  
- Solar system = 

Which diagram shows the correct relationship between these four regions? [If one symbol is within another symbol, that means it is part of, or included in, that symbol.]

A)  
B)  
C)  
D)  

71. The diagram below represents a standard dark-line spectrum for an element.

- Violet  
- Red

The spectral lines of this element are observed in light from a distant galaxy. Which diagram represents these spectral lines?

A)  
B)  
C)  
D)  
72. Which time line most accurately indicates when this sequence of events in earth's history occurred?
73. In the diagram below, the spectral lines of hydrogen gas from three galaxies, A, B, and C, are compared to the spectral lines of hydrogen gas observed in a laboratory.

What is the best inference that can be made concerning the movement of galaxies A, B, and C?

A) Galaxy A is moving away from Earth, but galaxies B and C are moving toward Earth.
B) Galaxy B is moving away from Earth, but galaxies A and C are moving toward Earth.
C) Galaxies A, B, and C are all moving toward Earth.
D) Galaxies A, B, and C are all moving away from Earth.

74. In which sequence are the items listed from least total mass to greatest total mass?

A) solar system, Milky Way, universe
B) Milky Way, solar system, universe
C) universe, Milky Way, solar system
D) Milky Way, universe, solar system
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>B</td>
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<tr>
<td>2.</td>
<td>D</td>
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<td>3.</td>
<td>D</td>
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<td>4.</td>
<td>A</td>
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<td>D</td>
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